EBRUARY 1961
LUME 4 • NUMBER 2

- Ernst — An Electron Density Measuring System for Hot Plasma Research
- Fank — Design of Low Noise Guns for Traveling Wave Tubes
- Pulfer — Microwave Superregenerative Amplifiers
- Gillard & Franks — Frequency Independent Antennas — Several New and Undeveloped Ideas

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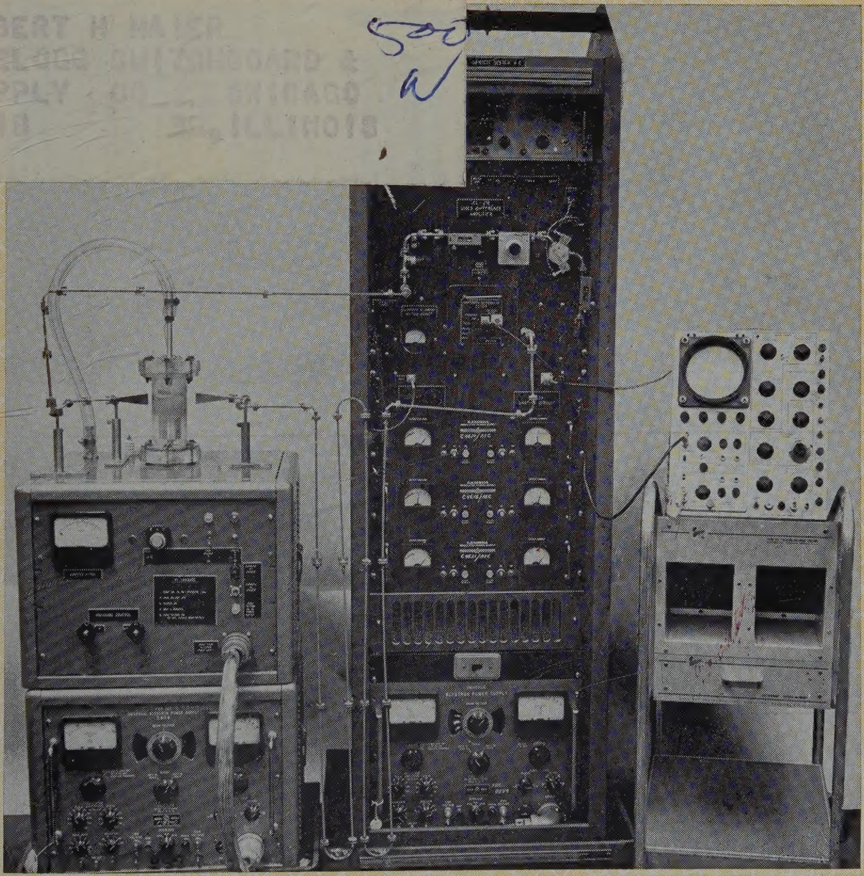

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the microwave journal

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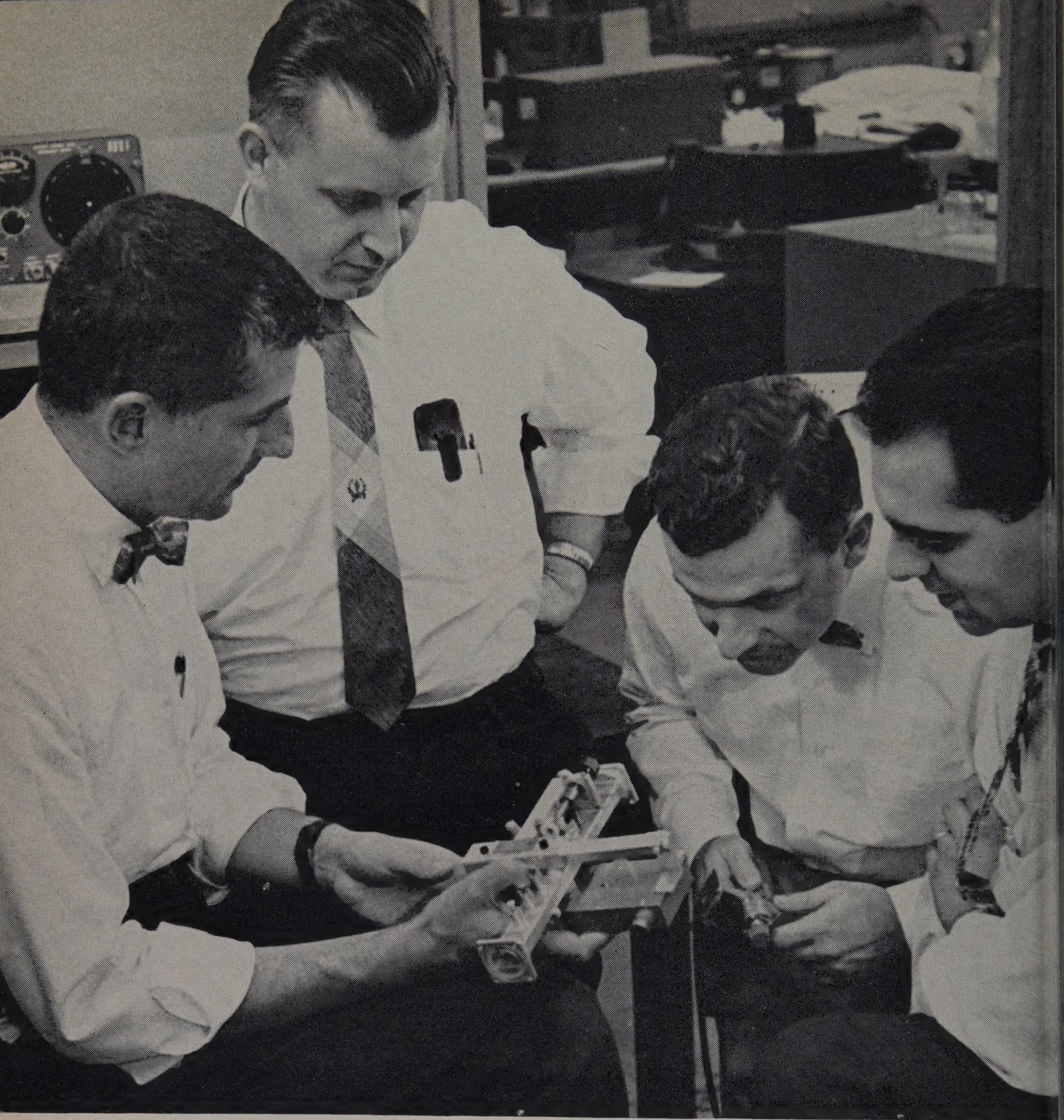

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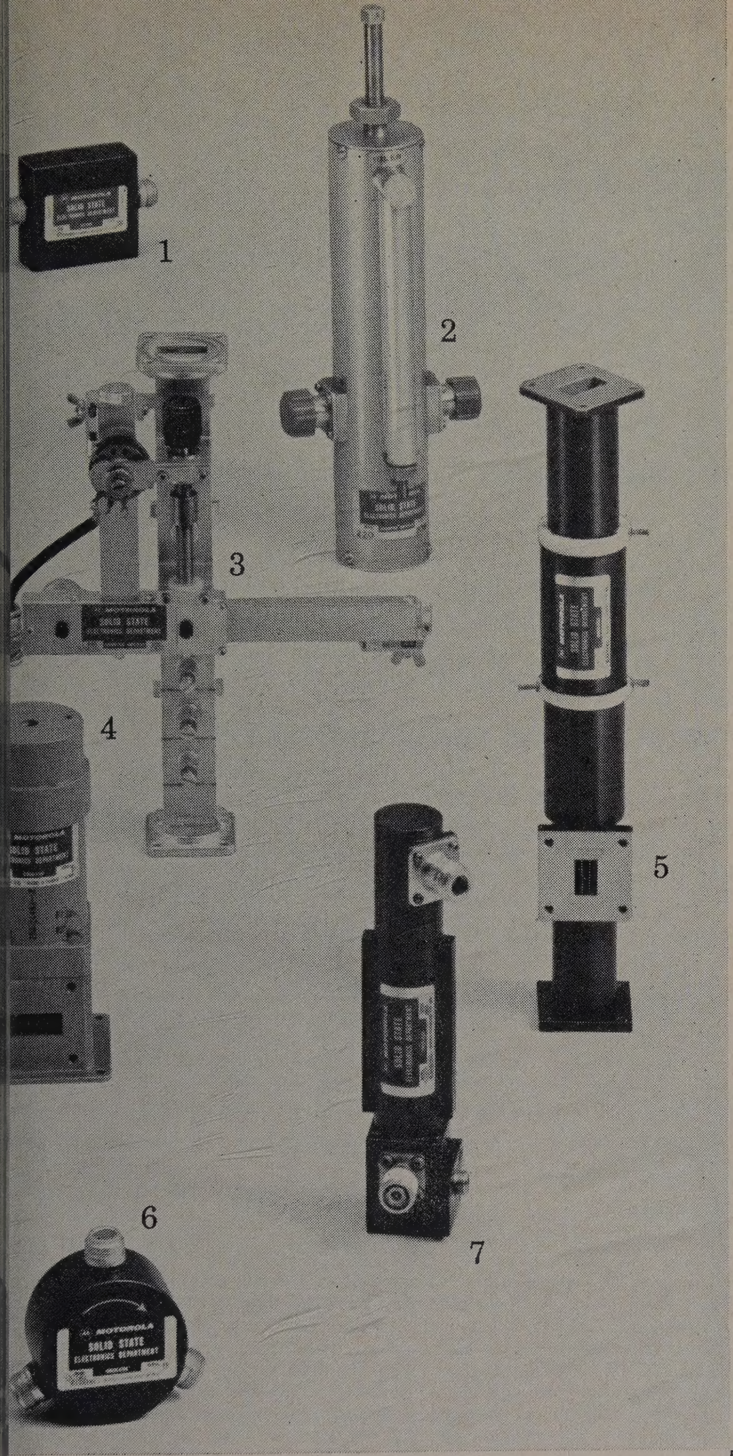

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MICROVIEWS
OF THE MONTH

49 ▶

AN ELECTRON DENSITY MEASURING SYSTEM FOR HOT PLASMA RESEARCH

William P. Ernst

An electron density measuring system utilizing a frequency sensitive microwave bridge network and associated electronics is described. Operating frequencies of 35 kMc or 70 kMc permit maximum electron density measurements of 1.5×10^{13} *and* 6.1×10^{13} *electrons/cm*^{3} *respectively. Simplified background theory is covered to establish the relationship of phase shift of the microwave signal through the plasma to the electron density within the plasma. Performance and function of the system's sub-sections are treated in some detail.*

55 ▶

DESIGN OF LOW NOISE GUNS FOR TRAVELING WAVE TUBES

F. B. Fank

The design of a low noise traveling wave tube is complicated by the many variables which affect its performance. It is the purpose of this paper to make available sufficient information with a straightforward design procedure so that the first design of a low noise tube can be made simply with a minimum of subsequent empirical work.

61 ▶

MICROWAVE SUPERREGENERATIVE AMPLIFIERS

J. K. Pulfer

The application of some of the more recent microwave oscillators as superregenerative amplifiers is discussed. The more important properties of superregenerative amplifiers are reviewed from the viewpoint of optimizing their use in receivers for detecting small microwave signals. Qualified results of theoretical and experimental investigations of the applications of backward wave oscillators, parametric oscillators, tunnel diodes, and other microwave devices as superregenerative amplifiers are given.

67 ▶

FREQUENCY INDEPENDENT ANTENNAS — SEVERAL NEW AND UNDEVELOPED IDEAS

C. W. Gillard and R. E. Franks

The primary purpose of this paper is to present ideas which, when developed, will increase the range of application and utility value of the frequency independent antenna. Several methods are described whereby frequency independent antenna performance with respect to pattern and impedance may be extended to aperture type antennas in the high gain class — 20 db *and above. In essence, such antennas feature a small, equiphase aperture with fixed illumination and a large collimating aperture; properly designed, the amplitude distribution at the collimating aperture of the system measured in terms of wavelength is constant and gives rise to a pattern which is remarkably independent of frequency. Ideas appropriate to low gain frequency independent antennas are briefly considered for the purpose of stimulating interest in this important field.*

OUR COVER

A 4 mm electron density measuring system is shown connected to a portable (low temperature) plasma source, which is used for system testing. See page 49.

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ONTROLLING RANS ARABIAN'S IPELINE VIA IGH DIRECTIVITY HF ARRAYS

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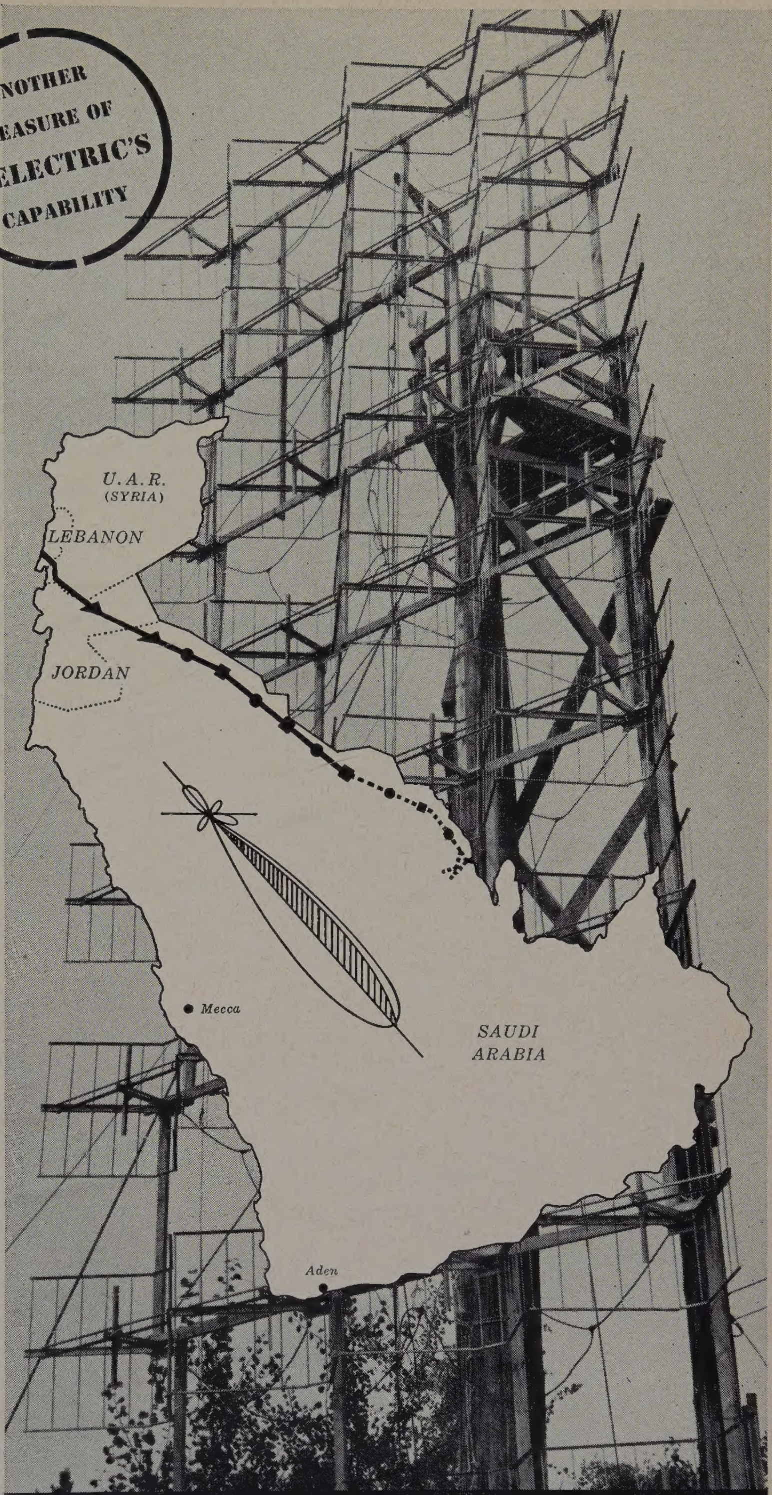

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from the editor

REPORT CARD

I have written many times about our editorial review policies. They are, as you probably know, strict.

All our papers are reviewed carefully, some are accepted as submitted, some are rejected outright, and others are sent back to the authors for revisions.

Since I have come out in print favoring statisticsmanship, I would like to give a few more statistics which should be of interest, especially to potential authors.

Now that we have adopted a policy of publishing four papers in each issue, we will need 48 accepted papers each year. (Based on comments made by many of you, we do not plan to increase the number of papers beyond four.)

Over the last several months we have processed 53 papers through our editors and editorial reviewers. Of the 53 papers, 27 were rejected for various reasons, 14 were accepted without revision, 5 were revised by the authors and later accepted, and 7 were returned to the authors for revisions with no further word from the authors to date.

The interesting thing is that less than half of the papers being submitted have been accepted and of those almost half are sent back for revision. It is a rather severe situation and demands much work on the part of all concerned.

Working backwards — in order to publish 48 papers each year, we must receive about 100 papers, of which 50 or more will be rejected, 25 or less will be accepted, and about 25 will be revised by the authors.

It is true that we would like to have a backlog of papers that have been processed and accepted. However, we have to be careful not to get too far ahead, otherwise the papers may become out-dated by the time they appear in print.

Papers take between 3 and 6 months from the time they are submitted by the author to the time the reader receives the completed magazine.

Occasionally, we have had papers take longer, and once in a while we have completed the cycle in 2 months.

Our processing has improved, and things move more smoothly with each passing issue, but we are still dependent on the individual microwave engineer to supply us with his handiwork.

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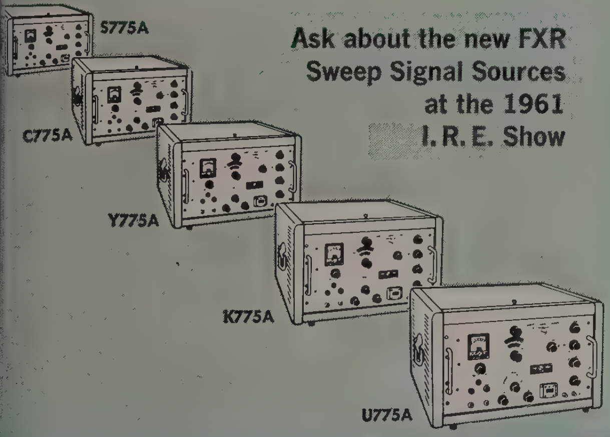

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X775A	8.2-12.4	20 mw	WR-90	UG-39/U	$2900.
Y775A	12.4-18.0	10 mw	WR-62	UG-419/U	$3300.
K775A	18.0-27.0	5 mw	WR-42	UG-595/U	$3700.
U775A	27.0-40.0	5 mw	WR-28	UG-599/U	$4300.

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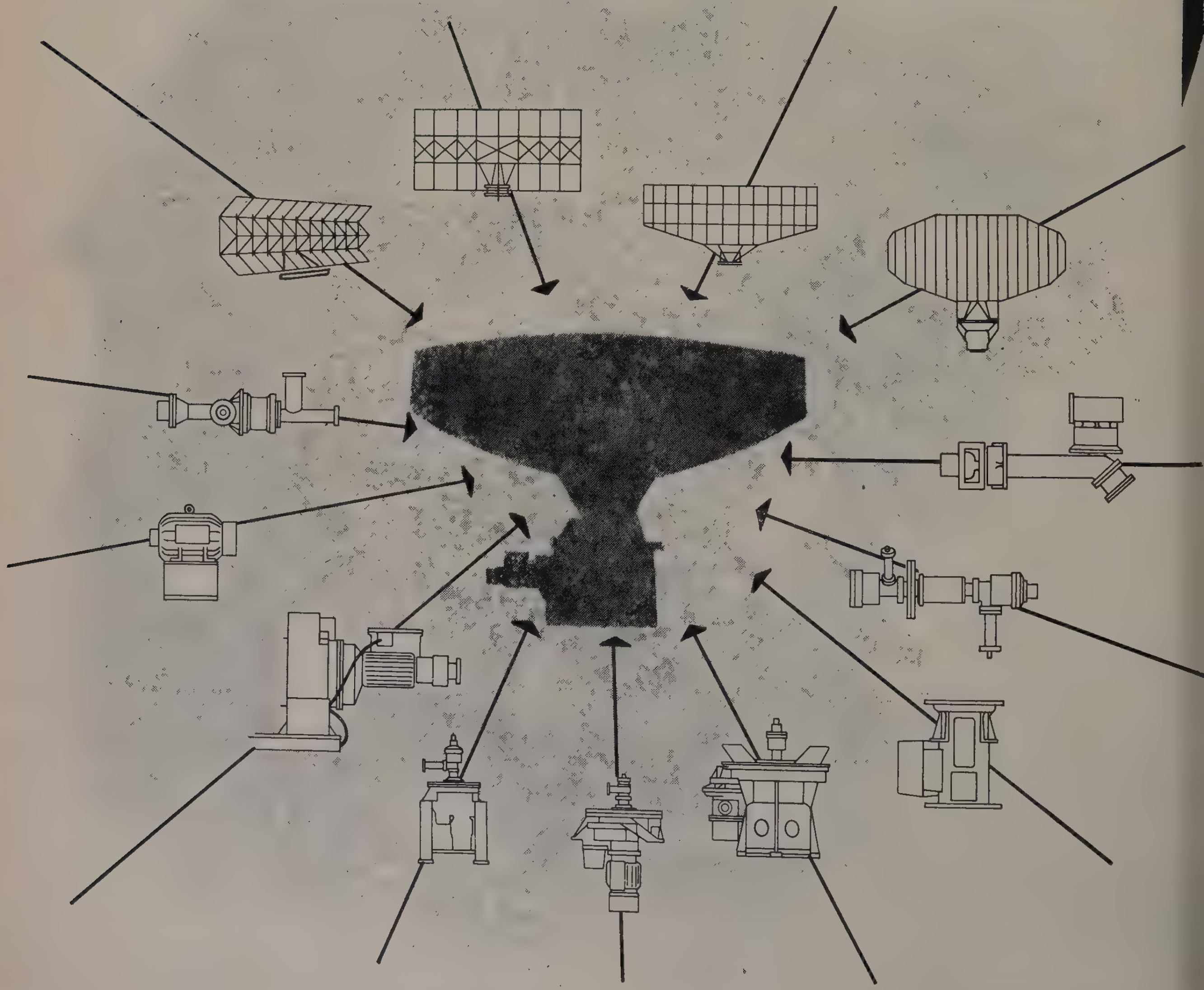

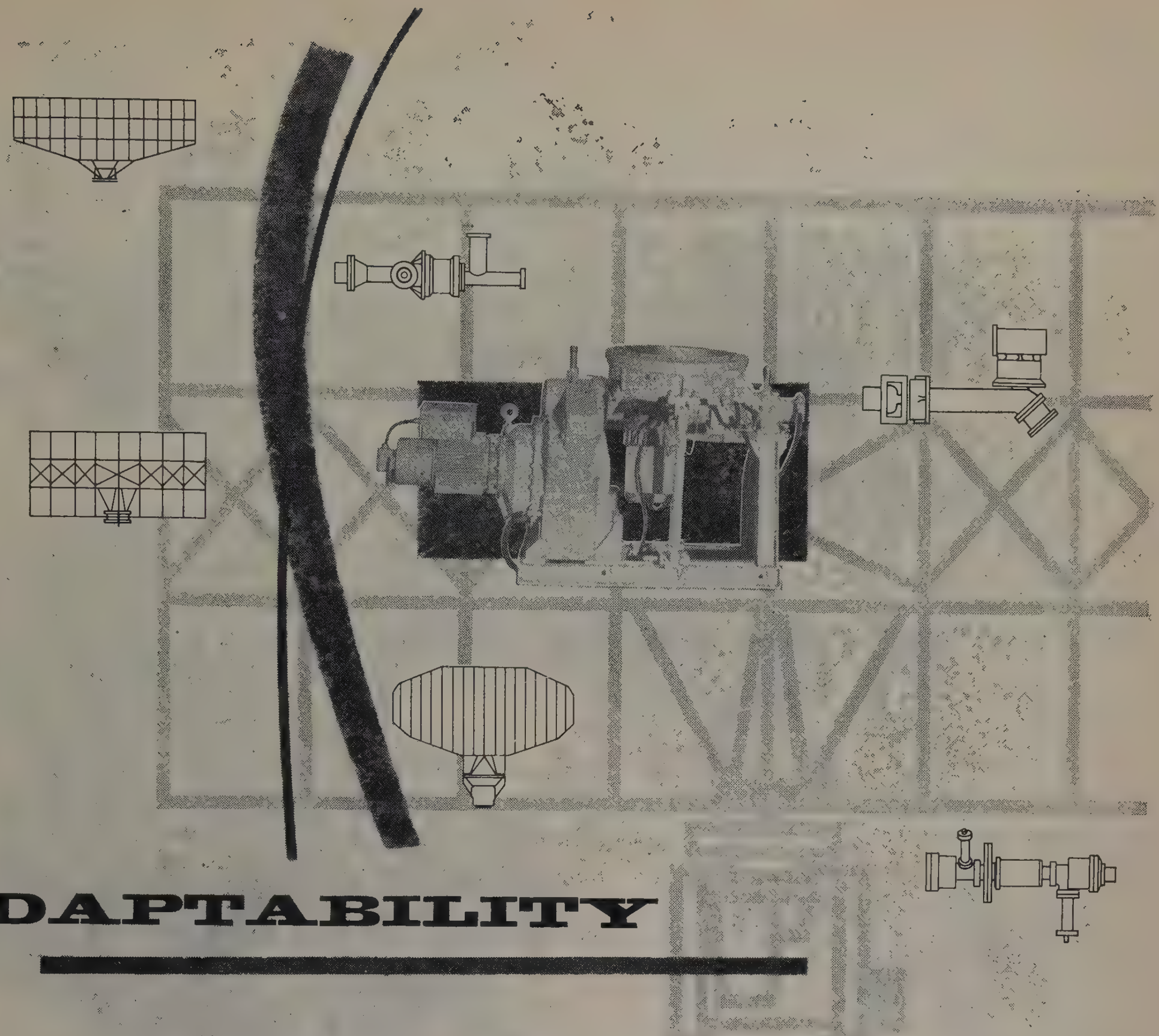

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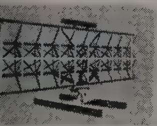

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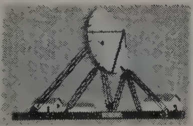
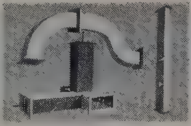


UHF ANTENNA SYSTEMS

PEDESTALS DRIVES • CONTROLS



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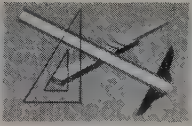

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Industry News

DORNE AND MARGOLIN APPOINT THREE PROGRAM MANAGERS

Appointment of three program managers has been announced by Dorne and Margolin, Inc., Westbury, L. I., N. Y., designer and maker of airborne antennas and microwave components.

D&M President Arthur Dorne said the new officials will be responsible for overall scheduling and planning of both engineering and production projects.

The appointees are:

Harold M. Horton, veteran D & M project engineer, who joined the company in 1952 following service with Airborne Instruments Laboratory and the Radio Research Laboratory at Harvard University. He will direct D&M projects in airborne and space antennas for communications and navigation.

Arnold Pellman, who was associated with Raytheon before recently joining D&M. At Raytheon, Mr. Pellman was project manager of the "Storm Finder Weather Radar System" developed for the U. S. Weather Bureau. Earlier, he served with General Precision, Arma, and General Electric. He will be in charge of D & M ground navigation projects.

Philip Auerbach, who came to D&M from the Arma Division of American Bosch Arma Corp., where he was section head of advance development and was responsible for gyro-navigation projects. At D&M, Mr. Auerbach will oversee electronics countermeasures activities.

— *m w j* —

PRITCHARD NAMED DIRECTOR OF ENGINEERING

Wilbur L. Pritchard has been named director of engineering for Selenia SpA in Europe. Selenia, one of the largest single electronics companies in Italy, was formed last year by Raytheon Company, "Finmeccanica" and "Societa Edison."

Pritchard formerly served as chief engineer for Raytheon Europe, one of the firm's operating divisions.

With Raytheon since 1946, Pritchard is a past president of the IRE national microwave group. He was graduated from the City College of New York with a BS in EE degree.

— *m w j* —

HUGHES WILL HIRE 2500 AT FULLERTON PLANT

Hughes Aircraft Company's ground systems plant, Fullerton, Cal., will hire more than 2500 persons during 1961, C. Harper Brubaker, a company vice president, has announced.

"Successful development of advanced land and sea-based radars, air defense systems, computers and electronic data display devices for the U. S. Army, U. S. Navy and the U. S. Marine Corps, has increased to 41 the number of multimillion dollar defense contracts now in work here," Brubaker said.

"We urgently need," Brubaker continued, "100 electro-mechanical designers and draftsmen, 150 electronic engineers, 60 electronic technicians, 30 test equipment engineers and 35 sheet metal assembly workers and machine operators."

The Hughes electronic engineering development and manufacturing facility located in Fullerton during 1957 with 800 employees. Current employment is more than 6500, while the weekly payroll exceeds $750,000, Brubaker said.

Recently announced by the department of defense was Frescan, a three-dimensional radar system, developed by Hughes' Fullerton plant, now operational with the fleet. Hughes ground systems has also developed and manufactured an advanced air defense system for the U. S. Army. Called Missile Monitor, this directs accurate firing of Nike and Hawk missiles against hostile aircraft, Brubaker explained. Missile Monitor is now deployed with the field army for the air defense of Europe.

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(*Continued on page 14*)

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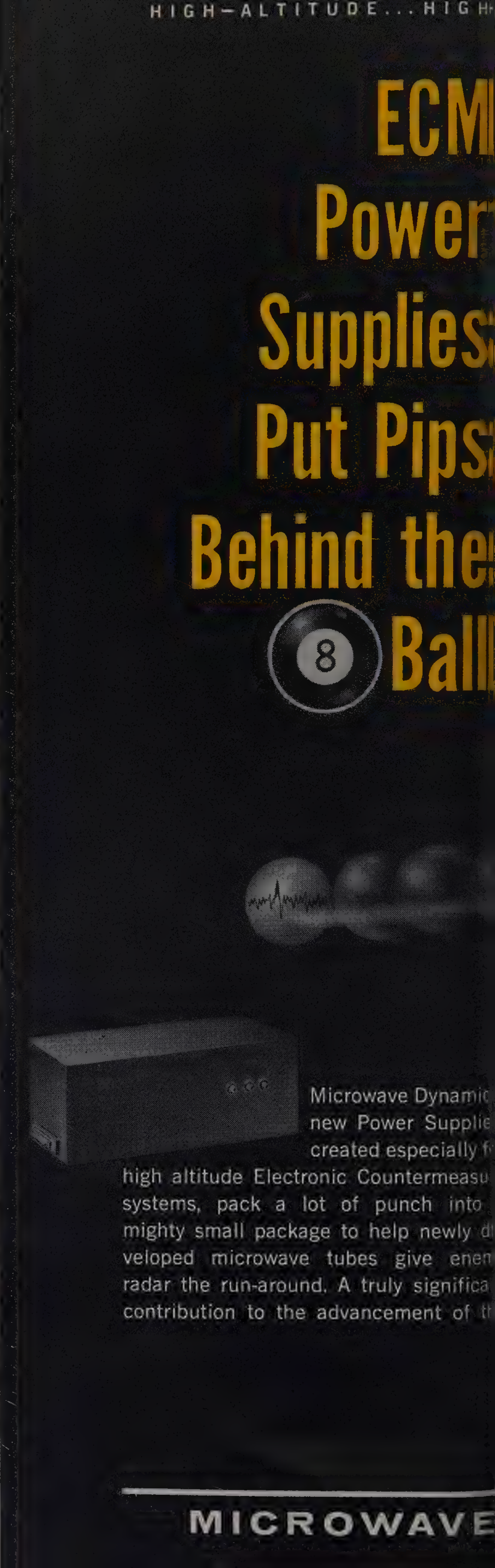
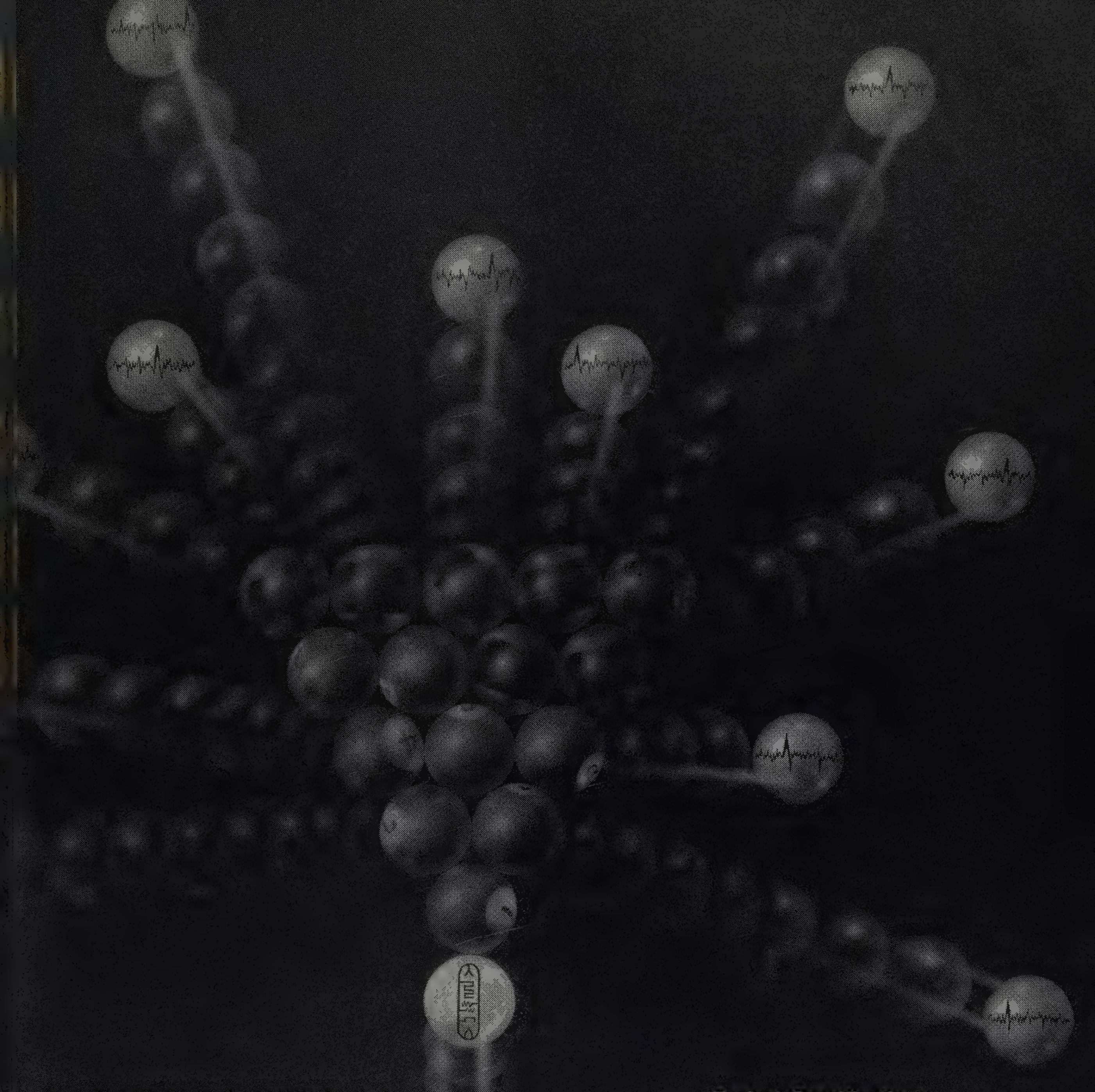


HIGH—ALTITUDE...HIGH

ECM
Power
Supplies
Put Pips
Behind the
8 Ball

Microwave Dynamic
new Power Supplie
created especially f
high altitude Electronic Countermeasu
systems, pack a lot of punch into
mighty small package to help newly d
veloped microwave tubes give enem
radar the run-around. A truly significa
contribution to the advancement of th

MICROWAVE



er-all countermeasures program, the
its will endure the most rigorous en-
ronmental conditions (MIL-E-5400) and
ep right on delivering, with "Reliability"
us. These novel, **high-altitude, high-
ltage, solid state, unpressurized, minia-
re power supplies** reflect Microwave
ynamics' keen awareness of the ever-
anging Microwave Industry.

Typical Specifications:

HIGH-VOLTAGE Supply

- 10,000 Volts dc, 40 milliamperes
- 6.3 Volts ac, 5 amperes
- −200 Volts dc, 1 milliampere
- +2500 Volts dc, 100 microamperes
- Weight— ~ 25 lbs.
- Total Volume— ~ 400 cu. in.

HIGH-POWER Supply

- 2000 Volts dc, 800 milliampere
- 12 Volts ac, 2.5 amperes
- Weight— ~ 15 lbs.
- Total Volume— ~ 225 cu. in.

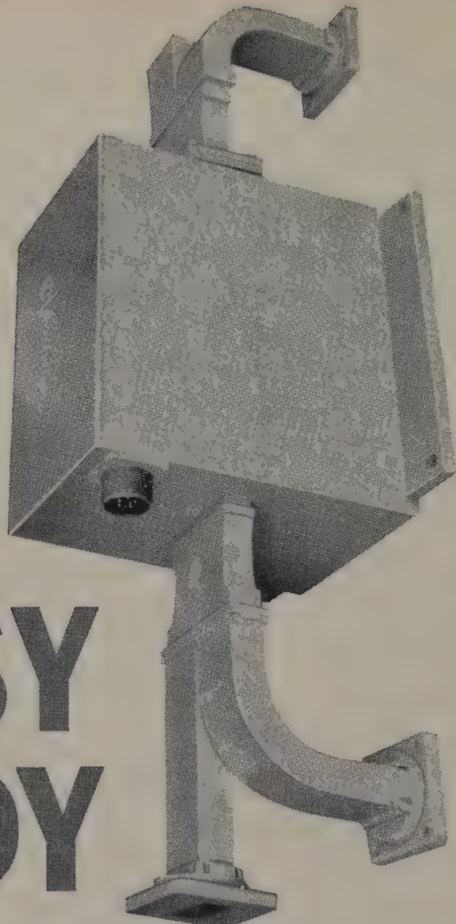
Complete information on custom and proprietary products available on request.

A Symbol of Reliability in the Microwave Field

NAMICS CORPORATION

a subsidiary of Talley Industries, Inc.

PLAINVIEW INDUSTRIAL PARK, PLAINVIEW, L. I., N. Y. • OVerbrook 1-6811



BUSY BODY

NOW HERE'S A SWITCH! This Airtron-designed ferrite switch has an odd habit. Unlike most ferrite devices, which are known and respected for their non-reciprocal ways, this one looks the same from either end.*

Used for time-sharing between altitude and azimuth antennas of a GCA radar system, our subject switches both transmitted and received signals to and from each antenna. Switching is accomplished by reversing the current in the coil which biases one of the ferrites. This changes the phase shift in the associated ferrite section, and the signal path changes from one alternate route to the other.

SPECIFICATIONS OF NOTE:

PEAK POWER:	250 KW	INSERTION LOSS:	0.65 DB MAX
AVERAGE POWER:	300 W	VSWR DURING SWITCHING:	1.2 MAX (terminated in matched load)
SWITCHING TIME:	10 mS	VSWR FULLY SWITCHED:	1.15 MAX (terminated in matched load)
ISOLATION BETWEEN ARMS:	20 DB MIN		

Ferrite switches are one of a number of microwave devices currently on our manufacturing schedule. Others include ferrite isolators, dummy loads, flexible waveguide, and waveguide hardware. May we tell you more?

*We mean, of course, that it looks the same to an entering signal. Ourselves, we know that there's a dummy load attached to an arm on one end, none on the other.

AIRTRON
A DIVISION OF LITTON INDUSTRIES

AIRTRON-MORRIS PLAINS • 200 EAST HANOVER AVENUE, MORRIS PLAINS, N. J.
GENERAL OFFICES AND ADVANCED DEVICES LABORATORIES, MORRIS PLAINS, N. J.

Circle Reader Service Card 7

Industry News

(*Continued from page 12*)

QUANTUM ELECTRONICS CONFERENCE TO BE HELD MARCH 23-25

The second international Conference on Quantum Electronics will be held in Berkeley, California, March 23-25, 1961. Emphasis will be placed on basic theory progress, and new research efforts in the field. Topics will include methods for the generation of millimeter and shorter waves, coherent sources and amplifiers (high frequency masers, irasers, lasers) and fundamental studies of materials and techniques suitable for the higher frequencies. The conference is sponsored by the Office of Naval Research.

Attendance will be limited to those active in research. Those interested should write to Professor J. R. Singer, chairman, Second International Conference on Quantum Electronics, Department of Electrical Engineering, University of California, Berkeley 4, California.

—*m w j*—

HASTINGS JOINS CANOGA STAFF

John P. Hastings has joined the staff of Canoga Electronics Corp., Van Nuys, Cal., as manager of Special Projects. His principal duties will be in the performance of engineering liaison on major military electronic systems.

Hastings formerly was manager of Field Operations for American Electronics Corp., Instrument Division; manager of Engineering Liaison for Interstate Electronics and a senior project engineer with the Ralph M. Parsons Company. Prior to this he was a communications officer with the U. S. Army Signal Corps for 12 years.

Hastings received his BSEE from Virginia Military Institute and his MSEE from the University of Illinois.

—*m w j*—

MCNAMARA NAMED SALES MANAGER FOR APPLIED DYNAMICS DIVISION

Leo V. McNamara has been appointed Sales Manager for the Applied Dynamics Division of the Atlee Corp., Waltham, Mass.

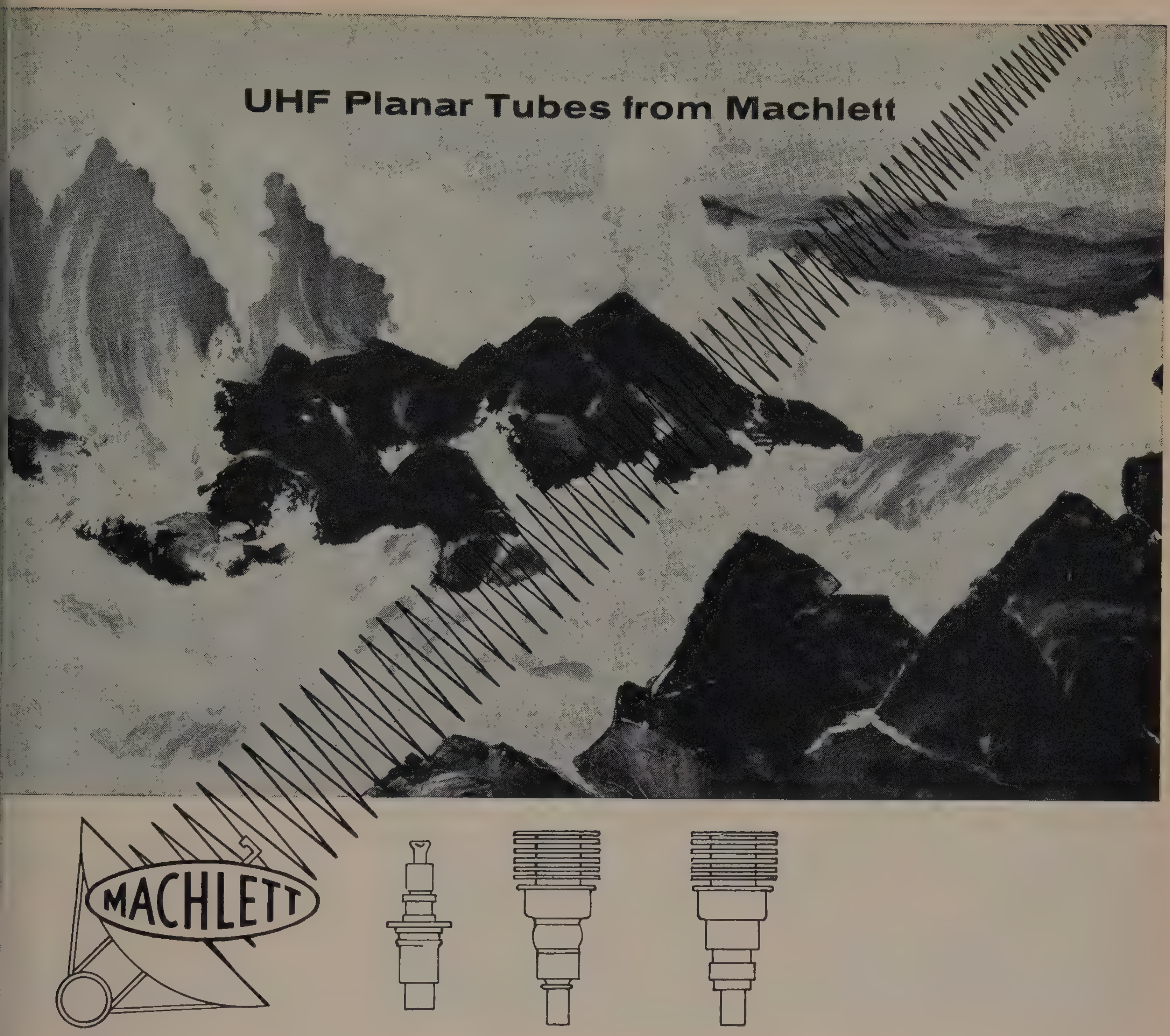
Bernard J. Warren, works manager for Applied Dynamics and Atlee's manager of Development Engineering, in announcing the appointment, indicated that McNamara's background in microwave and electronic test equipment, as well as electromechanical devices, will do much to broaden the scope of this division's sales program.

McNamara is a graduate of Lincoln Institute and is a member of the Northeastern University Alumni Association.

—*m w j*—

(*Continued on page 16*)

UHF Planar Tubes from Machlett



for Communications – Navigation – Telemetering – Radar & Missile Application

General purpose glass or ceramic planar triodes to 5000 mc/sec

• • •

Special purpose glass or ceramic planar triodes — examples of special characteristics now available:

- Quick warm-up (12 sec. cathode heating)
- High current cathode (150 ma plate current)
- Plate pulsed power
  (2 — 3kw to 3000 mc/sec)
  (2kw to 5000 mc/sec)
- Grid pulsed power
  (1½ to 2kw to 3000 mc/sec)

Machlett design *capability* in UHF planar tubes includes—

Mesh grid since 1945 (gold-plated tungsten mesh grid retains tight tolerance stability over broad thermal range. Detuning effects of sagging grid largely eliminated.)

NEW thermally stable anode (eliminates detuning effects of varying plate dissipation.)

Write now for the Machlett UHF Planar Tube Brochure — describing the industry's strongest line of planar tubes.

MACHLETT

THE MACHLETT LABORATORIES INCORPORATED

Springdale • Connecticut

Subsidiary of Raytheon Company

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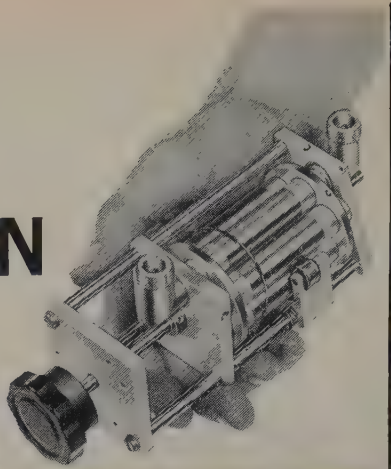
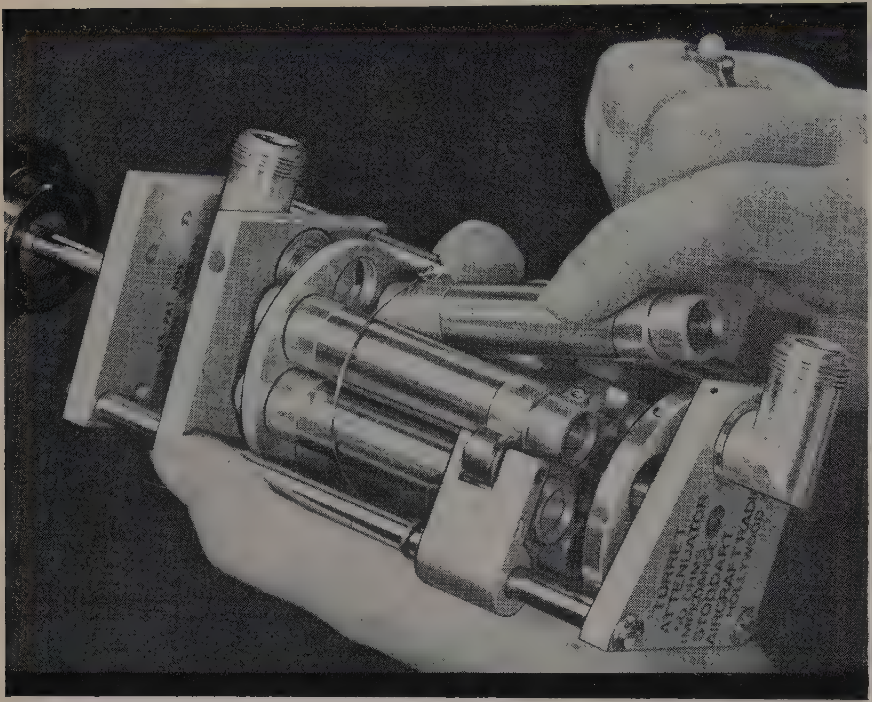
CHANGE db VALUES OF ATTENUATION IN SECONDS!





STODDART'S **new** turret attenuators* offer quick change of db combinations compatible to your system requirements.

Simply remove three set screws and the pad retainer ring moves forward for easy replacement, removal or rearrangement of pads.

NET BENEFITS TO USER . . .

- Easy pad replacement eliminates downtime otherwise required for unit or equipment dismantling.
- No increase in price!

*Patent applied for

16-page UHF Attenuator Catalog No. AT-3 gives complete details and specifications of new Stoddart attenuators, terminations and turret-type step attenuators.

ATTENUATORS

STODDART
AIRCRAFT RADIO CO., INC.
6644 Santa Monica Blvd., Hollywood 38, Calif HO 4-9292
serving 33 countries in radio interference control

Industry News

(*Continued from page 14*)

ESPOSITO NAMED CORPORATE PLANNER AT LOCKHEED

Robert V. Esposito has been appointed corporate planner at Lockheed Electronics Company, Plainfield, N. J., Dr. H. I. Ansoff, vice president for Plans and Programs, announced.

Mr. Esposito will participate in strategic market planning, competitive analyses, and evaluation of possible outside company acquisitions. He will make basic studies of markets and product areas that will permit the application of present products to new markets, of new products to present markets, and of new products to new markets.

A graduate of Duke University with the BA degree in economics, Mr. Esposito also holds the MS degree in market research from the Columbia University Graduate School of Business.

Before joining Lockheed Electronics, Mr. Esposito was employed for five years by the Research Division of the Prudential Insurance Co., Boston, Mass., as research consultant and assistant manager of the Research Division. Other positions held include project planner for Chance Vought Aircraft, Dallas, Tex., and senior research analyst for American Power Jet Company, Ridgefield, N. J.

—*mwj*—

RAYTHEON NAMES RUTHERFOORD DIRECTOR OF LICENSING

Appointment of J. Penn Rutherfoord to the newly-created position of director of licensing has been announced by the Raytheon Company, Waltham, Mass.

Richard E. Krafve, president of the electronics firm, said the new post was created to formulate and coordinate, with other company executives, over-all patent and know-how licensing policies for the company and its affiliates abroad. In addition, Rutherfoord will negotiate and administer licensing agreements.

Succeeding Rutherfoord as general manager of the firm's Commercial Apparatus and Systems Division is Robert E. Sonnekson who relinquishes his post as manager of the Equipment Division's Airborne Equipment Operations.

John G. Stobo, formerly manager of manufacturing for Airborne Equipment Operations succeeds Sonnekson.

—*mwj*—

(*Continued on page 23*)

New Weinschel Plug-in RF Sources for Precision Microwave Measurements provide exceptional amplitude and frequency stability, cover a wide frequency range with true single knob control.

Six new RF Sources, which cover the frequency range of 50 to 10,500 MCS and plug into a common Power Supply-Modulator, have been developed by Weinschel Engineering to meet the demand for stable sources for CW or 100% square-wave modulated RF Power for precise microwave measurements.

For ease of operation, the Power Supply-Modulator, Model MO-3, automatically selects the proper meter range and all the voltages necessary to operate each of the RF Sources without adjustments, thus providing true single knob control. In addition, when a source is plugged into the Power Supply-Modulator, the application of high voltages is automatically delayed until the warm-up of tube filaments is complete.

Klystrons are used above 900 MCS. Castings with integral bearings provide for all moving parts a rigid support which is independent of possible bending of the panel. This rugged construction results in maximum amplitude and frequency stability. The super-honed cavities and non-contacting, low loss, Z-type shorts assure long, reliable and maintenance-free service.

Key Specifications are: *(After 30 minutes' warm-up)*

Stability of output power (both CW or Modulated): Better than 1% in 8 hours (for constant load).

Stability of Frequency of 1000 cps Modulator: Better than .01%.

Frequency Stability: 50 to 920 MCS: better than ± .1%. 900 to 10,500 MCS: Better than 1 part in 10^4 in 8 hours, better than 1 part in 10^5 in 15 minutes.

MODEL NO.	FREQUENCY MCS	FOR 50 OHM LOAD	
		MINIMUM POWER OUTPUT, CW	MINIMUM PEAK POWER OUTPUT (100% Square Wave Modulated)
MS-12	50-250	40 MW	40 MW
MS-13	250-920	100 MW	100 MW
MS-8	900-2200	20 MW	20 MW
MS-9	2100-4200	2100-2600 MCS: 30 MW 2600-4200 MCS: 50 MW	2100-2600 MCS: 30 MW 2600-4200 MCS: 50 MW
MS-10	4000-7300	50 MW	50 MW
MS-11	7200-10,500	7200-7400 MCS: 20 MW 7400-9700 MCS: 50 MW 9700-10,500 MCS: 20 MW	7200-7400 MCS: 20 MW 7400-9700 MCS: 50 MW 9700-10,500 MCS: 20 MW

Write for complete specifications.

WEINSCHEL ENGINEERING®

WE CO

KENSINGTON, MARYLAND Phone: LOckwood 4-0121 TWX Kensington, Maryland 446

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SPERRY Microline®

FREQUENCY

NEW

NEW

DIRECT READING FREQUENCY METERS

MODEL	FREQUENCY (GC)	ACCURACY (%)	PRICE	
12L1	.66- 3.00 (coax)	.1	$550	
12S1	2.60- 3.95	.08	$450	
12C1	3.95- 5.85	.08	$250	
12G1	5.85- 8.20	.08	$250	Available September 1
12H1	7.05-10.00	.08	$195	Available September 1
12X1	8.20-12.40	.08	$150	
12U1	12.40-18.00	.1	$210	
12K1	18.00-26.50	.1	$230	
12V1	26.50-40.00	.2	$250	Available September 1

PRECISION FREQUENCY METERS

MODEL	FREQUENCY (GC)	ACCURACY (%)	PRICE
14S1	2.575- 3.780 (coax)	.01	$850
14C1	4.01 - 6.00	.01	$565
14G1	5.49 - 8.10	.01	$450
14X1	8.10 -11.90	.01	$450

IMPEDANCE

NEW

SLOTTED LINES AND PROBE

MODEL	FREQUENCY (GC)	DESCRIPTION	PRICE	
21A1	—	Universal Carriage	$160	
21B1	1.00-18.00	Broadband Probe	$125	
21L1	1.12- 1.70	Slotted Line	$800	
21S1	2.60- 3.95	Slotted Line	$450	
21C1	3.95- 5.85	Slotted Section	$110	
21G1	5.85- 8.20	Slotted Section	$100	Available Now
21H1	7.05-10.00	Slotted Section	$100	Available Now
21X1	8.20-12.40	Slotted Section	$ 90	
21U1	12.40-18.00	Slotted Section	$110	

ALL NEW

TUNERS

MODEL	FREQUENCY (GC)	TYPE	PRICE	
22S1	2.60- 3.95	Slide Screw	$225	All Available June 15
22C1	3.95- 5.85	Slide Screw	$180	
22G1	5.85- 8.20	Slide Screw	$150	
22H1	7.05-10.00	Slide Screw	$130	
22X1	8.20-12.40	Slide Screw	$125	
22U1	12.40-18.00	Slide Screw	$130	
22U2	12.40-18.00	E-H	$150	
22K2	18.00-26.50	E-H	$180	
22V2	26.50-40.00	E-H	$220	

REFLECTOMETER COUPLERS

MODEL	FREQUENCY (GC)	COUPLING (db)	PRICE
24S1	2.60- 3.95	10	$600
24G1	3.95- 5.85	10	$350
24X1	8.20-12.40	10	$175

ADJUSTABLE SHORTS

MODEL	FREQUENCY (GC)	TYPE DRIVE	PRICE
23S1	2.60- 3.95	Knob	$100
23C1	3.95- 5.85	Knob	$ 70
23G1	5.85- 8.20	Knob	$ 60
23H1	7.05-10.00	Knob	$ 50
23X1	8.20-12.40	Knob	$ 40
23U1	12.40-18.00	Micrometer	$ 90
23K1	18.00-26.50	Micrometer	$130
23V1	26.50-40.00	Micrometer	$140

SPERRY

SPERRY MICROWAVE ELECTRONICS COMPANY, *CLEARWATER, FLORIDA • DIVISION OF SPERRY RAND CORPORATIO*

Microline Instruments *• Radar Test Sets • Systems Instrumentation • Solid State Devices and Materials • Microwave Components and Antenn*

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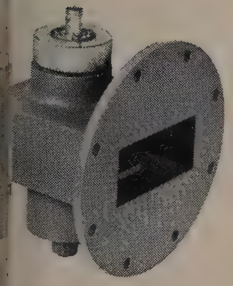
MEASURES . . .

POWER



NEW

NEW

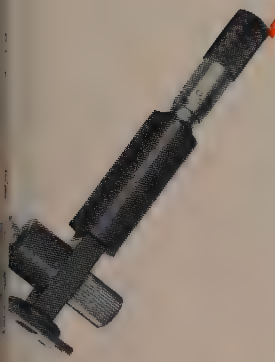
BARRETTER MOUNTS

MODEL	FREQUENCY (GC)	MAX VSWR	PRICE	
33B3	.50-11.00 (coax)	1.5	$ 75	Available Now
33L1	.95- 1.22 (coax)	1.3	$100	
33S2	2.60- 3.95	1.35	$150	
33C2	3.95- 5.85	1.5	$140	
33G2	5.85- 8.20	1.5	$130	
33H2	7.05-10.00	1.5	$100	Available July 15
33X2	8.20-12.40	1.5	$ 70	

ALL NEW

THERMISTOR MOUNTS

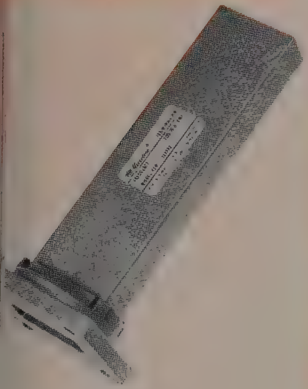
MODEL	FREQUENCY (GC)	MAX VSWR	PRICE	
33B2	.50-11.00 (coax)	1.5	$ 75	
33S3	2.60- 3.95	1.5	$120	Available June 15
33C3	3.95- 5.85	1.5	$ 95	Available June 15
33G3	5.85- 8.20	1.5	$ 90	Available June 15
33H3	7.05-10.00	1.5	$ 80	Available June 15
33X3	8.20-12.40	1.5	$ 75	Available June 15
33U3	12.40-18.00	1.5	$110	Available November 15
33K3	18.00-26.50	2.0	$150	Available November 15
33V3	26.50-40.00	2.0	$220	Available November 15



TUNABLE DETECTOR MOUNTS

MODEL	FREQUENCY (GC)	TYPE	PRICE
34B1	1.00-10.00 (coax)	Knob	$125
34S1	2.60- 3.95	Knob	$180
34C1	3.95- 5.85	Knob	$ 95
34G1	5.85- 8.20	Knob	$ 90
34H1	7.05-10.00	Knob	$ 85
34X1	8.20-12.40	Knob	$ 75
34U1	12.40-18.00	Micrometer	$160
34K1	18.00-26.50	Micrometer	$170
34V1	26.50-40.00	Micrometer	$180

ATTENUATION



LOW POWER TERMINATIONS

MODEL	FREQUENCY (GC)	MAX VSWR	PRICE
42S1	2.60- 3.95	1.01	$50
42C1	3.95- 5.85	1.01	$40
42G1	5.85- 8.20	1.01	$35
42H1	7.05-10.00	1.01	$30
42X1	8.20-12.40	1.01	$25
42U1	12.40-18.00	1.015	$30
42K1	18.00-26.50	1.015	$30
42U1	26.50-40.00	1.015	$35

HIGH POWER TERMINATIONS

MODEL	FREQUENCY (GC)	MAX VSWR	PRICE
43S1	2.60- 3.95	1.15	$150
43C1	3.95- 5.85	1.15	$140
43H1	7.05-10.00	1.15	$100
43X1	8.20-12.40	1.15	$ 85

ALL NEW

CROSSGUIDE COUPLERS

MODEL	FREQUENCY (CG)	COUPLING (db)	PRICE	
44S3	2.60- 3.95	20, 30	$150	All Available May 15
44C3	3.95- 5.85	20, 30	$130	
44G3	5.85- 8.20	20	$ 90	
44H3	7.05-10.00	20	$ 80	
44X3	8.20-12.40	20, 30	$ 60	

SPERRY

PERRY MICROWAVE ELECTRONICS COMPANY, *CLEARWATER, FLORIDA • DIVISION OF SPERRY RAND CORPORATION*

icroline Instruments • *Radar Test Sets • Systems Instrumentation • Solid State Devices and Materials • Microwave Components and Antennas*

SPERRY *Microline*® MEASURES...

ATTENUATION

MULTIHOLE COUPLERS

ALL NEW

MODEL	FREQUENCY (GC)	COUPLING (db)	PRICE
45S1	2.60- 3.95	3, 10, 20	$375
45C1	3.95- 5.85	3, 10, 20	$250
45G1	5.85- 8.20	3, 10, 20	$140
45H1	7.05-10.00	3, 10, 20	$120
45X1	8.20-12.40	3, 10, 20	$100
45U1	12.40-18.00	3, 10, 20	$115
45K1	18.00-26.50	3, 10, 20	$175
45V1	26.50-40.00	3, 10, 20	$200

All Available June 15

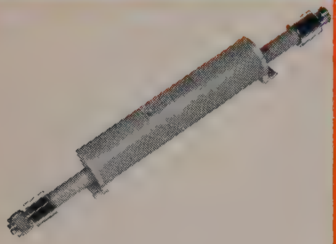
LEVEL SET ATTENUATORS

MODEL	FREQUENCY (GC)	RANGE (db)	PRICE
47X1	8.20-12.40	0-18	$ 45
47U1	12.40-18.00	0-18	$ 50
47S2	2.60- 3.95	0-40	$115
47C2	3.95- 5.85	0-40	$105
47G2	5.85- 8.20	0-40	$100
47H2	7.05-10.00	0-40	$ 90
47X2	8.20-12.40	0-40	$ 70
47U2	12.40-18.00	0-40	$ 85
47K2	18.00-26.50	0-40	$140
47V2	26.50-40.00	0-40	$170

ALL NEW

All Available July 15

ACCESSORY INSTRUMENTS

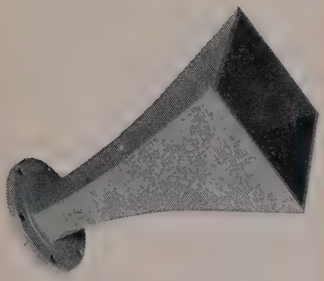


COAX ISOLATORS

MODEL	FREQUENCY (GC)	ISOLATION (db)	PRICE
72L2	1-2	15	$300
72S2	2-4	15	$300
72C2	4-7	20	$300
72H2	7-11	20	$180

ADAPTERS

MODEL	FREQUENCY (GC)	CONNECTORS	PRICE
54B1	0-4 (Coax)	UG45 to UG45	$40
54B2	0-4 (Coax)	UG46 to UG46	$40
54B3	0-4 (Coax)	UG46 to N	$40
54B4	0-4 (Coax)	UG45 to N	$40
54K2	18.00-26.50	UG425 to UG595	$25
54V2	18.00-26.50	UG381 to UG599	$25
54S1	2.60- 3.95	UG214 to UG45	$70
54C1	3.95- 5.85	UG149 to N	$40
54X1	8.20-12.40	UG39 to N	$35



STANDARD GAIN HORNS

MODEL	FREQUENCY (GC)	GAIN (db)	PRICE
56S1	2.60- 3.95	15	$175
56C1	3.95- 5.85	15	$150
56G1	5.85- 8.20	15	$125
56H1	7.05-10.00	15	$120
56X1	8.20-12.40	15	$ 90
56U1	12.40-18.00	15	$110
56K1	18.00-26.50	15	$110
56V1	26.50-40.00	15	$110

WAVEGUIDE ISOLATORS

SPERRY

ALL NEW

MODEL	FREQUENCY (GC)	MIN. ISOLATION (db)	AV. POWER (watts)
73S1	2.60-3.95	15	10
73C1	3.95-5.85	20	10
73G1	5.85-8.20	25	10
73X1	8.20-12.40	25	10

SPERRY MICROWAVE ELECTRONICS COMPANY, *CLEARWATER, FLORIDA · DIVISION OF SPERRY RAND CORPORATIO*

Microline Instruments • *Radar Test Sets* • *Systems Instrumentation* • *Solid State Devices and Materials* • *Microwave Components and Antenna*

Circle Reader Service Card 13

IORE SPERRY *Microline*® INSTRUMENTS

EW!

Available April 15

MODEL 59A1

ADJUSTABLE WAVEGUIDE STAND

- The most convenient and useful waveguide stand ever to hit the market. Made of high impact plastic, this unit continuously adjusts to accommodate waveguide from S-Band (3X1) to V-Band (.36X.22). Independent vertical adjustment is from 2 inches to 4 inches; provision is made for permanent clamping to bench or table.

Available Sept. 15

MODEL 64X1

MICROWAVE SWEPT OSCILLATOR

- Very versatile microwave source for entire range of X-band, 8.2 - 12.4 Gc...Can be swept in either direction with sweep durations from 10 milliseconds to 100 seconds . . . High and low end points independently adjustable . . . Electronic and relay marker output signals at end points and at three independently adjustable markers . . . Instant selection of spot frequencies corresponding to either end point or any marker . . . Automatic or triggered sweep . . . Frequency indicated on front panel meter for sweep monitoring and end points shown on main dial to 1% . . . Internal 1000 cps modulation, external modulation or CW operation . . . Internal or external microwave level control . . . Power output 20 milliwatts minimum.

Available July 15

MODEL 61A1

MICROWAVE RECEIVER

- Precision parallel substitution microwave receiver with automatic null indication to better than .02 db . . . 100 db range reference attenuator with .05 db/10 db accuracy . . . 2.5 db noise figure on the 30 mc i-f strip with 1 mc bandwidth...linear or log operation. AFC circuit adapts any power supply for frequency control of your BWO or klystron with voltages up to 5000 volts. AFC control from internal i-f strip or external signal source.

SWR NDICATOR

SWR INDICATOR MODEL 29A1
Microline

- Many features designed into the 29A1 are not normally included at such a low price. And it is available for immediate delivery.

Adjustable bandwidth allows maximum sensitivity with freedom from modulator drift errors. Positive protection against bolometer burnout. Expanded scale with automatic gain compensation. Push-to-read bolometer current. Plus 5 db gain supplement always assures accurate upscale meter readings. Designed for ease of operation.

FREQUENCY:	1000 cps ± 1%
SENSITIVITY:	0.1 uv for full scale deflection
NOISE LEVEL:	Less than 0.03 uv at min. bandwidth
BANDWIDTH:	Wide Band: 300 - 5000 cps Narrow Band: continuously adjustable 30 - 150 cps
RANGE:	70 db adjustable in 5 db steps accurate to ± .1 db per step
RECORDER OUTPUT:	0 to 1 ma, 1500 ohms, one side grounded
DIMENSIONS:	Approx. 8″ x 11″ x 12″
PRICE:	$200

AVERAGE POWER METER

AVERAGE POWER METER MODEL 31A1
Microline

- 3% accuracy makes it the most accurate instrument of its kind on the market. Has unmatched stability. Sperry Microline 31A1 can be used to measure pulsed or C-W power of radar, radio, television, microwave and microwave relay equipment and components. Priced competitively low.

In addition, two scales (0-10 db and 5-15 db) permit its use for direct attenuation measurements. Its frequency coverage is limited only by the range of the bolometer and mount used. D-C bias adjustment is set by a 12-position switch.

SCALES:	Five ranges, front panel selection: 0-.1, 0-.3, 0-1.0, 0-3.0, 0-10 milliwatts full scale. Two ranges 0-10, 5-15 db full scale. Higher power levels by using directional couplers and/or calibrated attenuators.
ACCURACY:	3% of full scale reading.
POWER:	105-125 volts, 210-230 volts, 50-60 cps.
BOLOMETER:	Temperature coefficient: positive or negative, front panel selected. Resistance: 100 or 200 ohms, front panel selected.
BIAS CURRENT:	0-16 ma d-c
RECORDER OUTPUT:	0-1 ma, 1500 ohms, one side ground
OSCILLATOR FREQUENCY:	10.7 kc.
WEIGHT:	Approximately 13 lbs.
PRICE:	$240

SPERRY

ERRY MICROWAVE ELECTRONICS COMPANY, *CLEARWATER, FLORIDA • DIVISION OF SPERRY RAND CORPORATION*

croline Instruments *• Radar Test Sets • Systems Instrumentation • Solid State Devices and Materials • Microwave Components and Antennas*

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MORE SPERRY *Microline*® INSTRUMENTS

PEAK POWER METER

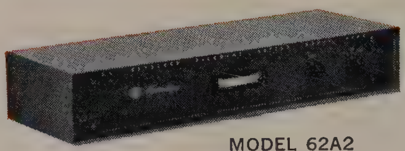
- Direct peak power measurements may be made quickly, conveniently and accurately with the Microline 31A2 Peak Power Meter. This unit operates on the unique barretter integration-differentiation technique developed by Sperry. Used in conjunction with an external barretter and mount, the model 31A2 measures up to 300 milliwatts directly; higher powers may be measured by use of an appropriate directional coupler.

REPETITION RATE:	50 to 5000 pps
PULSE WIDTH:	0.25 to 10 microseconds
RISE TIME:	0.15 microseconds
POWER RANGES:	0-30, 0-100, 0-300 mw
FREQUENCY RANGE:	depends on Barretter Mount
BARRETTER MOUNT OUTPUT:	Capacitance must be less than 100 mmf
VIDEO OUTPUT:	300 millivolts
ACCURACY:	±10%

PEAK POWER METER MODEL 31A2
Microline

WEIGHT:	Approx. 20 lbs.
PRICE:	$1200

KLYSTRON POWER SUPPLIES



MODEL 62A2
PRICE $240

MODEL 62A1
PRICE $1300

This is the Microline power trio. On the left is the Sperry Microline 62A2 DC Klystron Filament Supply . . . a regulated source of filament power for the most critical laboratory measurements. With insulation for beam supplies up to 4000 volts, it can supply up to 2 amperes with output voltage ranging from 2.5 to 10 volts, continuously adjustable. Regulation is 0.5% for 105-125 volt line and 1% for any combination of line or load, with maximum 10 mv ripple.

In the center is the Sperry Microline 62A1 Universal Klystron Power Supply . . . the widest range supply with highest beam power available but the smallest package of any. In 10½ inches of panel space are a 200-4000 volt beam supply with 360 watt capacity (150 ma maximum) and 0.01% regulation, a complete klystron modulator, 1000 volt reflector supply with 0.01% regulation, positive and negative grid supply . . . all weighing only 125 pounds including the case.

At the right is the newest member of the Microline power supply family; the Sperry Microline 62A3 Klystron Power Supply. This unit supplies all the many types of lab klystrons with beam voltages 200-700 volts and using up to 70 ma. It has the same modulator as the 62A1 and a 1000 volt reflector supply. This is a small lightweight (32 pounds) supply which will handle 75% or more of lab klystrons.

For detailed specifications, contact your Microline Representative.

MODEL 62A3
PRICE $550

SPERRY MICROWAVE ELECTRONICS COMPANY

CLEARWATER, FLORIDA

DIVISION OF SPERRY RAND CORPORATION

VISIT US AT
I.R.E.
SHOW
NEW YORK
MARCH
20 - 23

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Seattle, Wash.

Circle Reader Service Card 15

(*Continued from page 16*)

PORTER, LEE NAMED VICE SIDENTS AT HEWLETT-PACKARD

wlett-Packard Company, Palo Alto, manufacturer of electronic measuring uments, has announced two vice- dential appointments within the pany.

pel E. Porter, former vice president manufacturing, will occupy the new of vice president of operations.

lph E. Lee, formerly chief manufac- g engineer, will succeed Mr. Porter ice president of manufacturing.

r. Porter's new responsibilities will de the coordination of Hewlett- ard divisions and subsidiaries.

r. Lee's new duties will include onsibility for manufacturing engineer- plant engineering, quality assurance, engineering, and various engineering ort activities.

— *m w j* —

TORGOW NAMED DORNE & MARGOLIN CHIEF ENGINEER

gene N. Torgow, microwave research alist, has been appointed chief engineer of Dorne and Margolin, Inc., Westbury, L. I., N. Y., a designer and maker of airborne antennas and microwave components, Arthur Dorne, D&M president announced. The firm plans a marked increase in its microwave acti- Mr. Dorne said.

r. Torgow joined Dorne and Margolin eptember, 1960, and has been heading ompany's Microwave Group.

e was in charge of the Special Pro- s Department of the Polytechnic Re- h and Development Company prior oming with Dorne and Margolin.

1948, Mr. Torgow became a member he staff of the Microwave Research tute of the Polytechnic Institute of klyn, N. Y., where he worked on rch and development of microwave uators and power measuring devices engaged in strip line and waveguide development.

e became leader of the Component arch Section in 1957 after having es- shed and supervised a microwave ratory at the Allen B. Dumont Labor- ies, East Paterson, N. J.

r. Torgow received his BEE degree Cooper Union School of Engineering 946 and his MEE degree from Poly- nic Institute in Brooklyn in 1949.

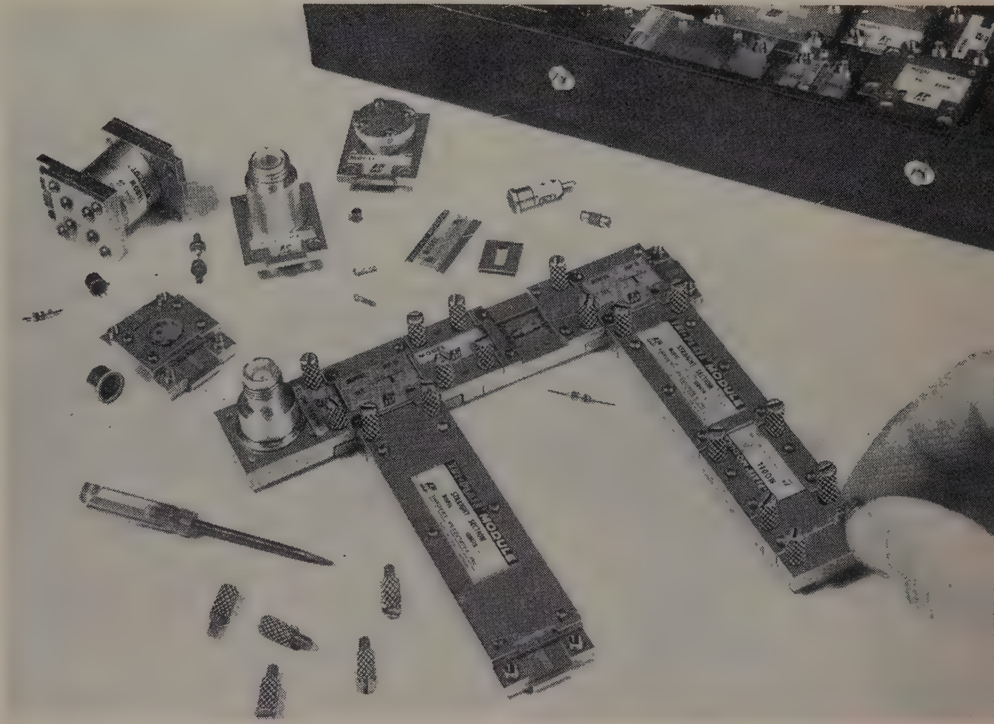
e is a member of Sigma Xi and a or member of the IRE, serving on the Admissions Committee and as vice rman of the Administrative Commit- of the New York Chapter of the IRE essional Group on Microwave Theory Techniques.

— *m w j* —

(*Continued on page 24*)

NEW KITS SPEED BREADBOARDING OF ADVANCED VARACTOR, TUNNEL DIODE AND TRANSISTOR CIRCUITS!

Harmonic generators, parametric amplifiers, oscillators, pulse amplifiers and down convertors are now assembled in minutes with Sanders TRI-PLATE® *Modules!*



This new dimension in semiconductor circuit design offers nearly limitless combinations. In a matter of minutes complete circuit subassemblies using series or shunt 1, 2, 3 or 4 port mounts with choice of RF by-pass, ground return and/or bias provision can be constructed.

Sanders new TRI-PLATE semiconductor mount kits accommodate 11 of the most commonly used semiconductor device packages. Such configurations as series, double ended cartridges, pigtail diodes, TO 18 and TO 5 transistor packages and ceramic cartridges are merely placed in one of the various TRI-PLATE semiconductor mounts.

The new TRI-PLATE semiconductor mount kits extend and supplement standard TRI-PLATE strip transmission line module kits for sub-nano-second switching speeds up to 7 KMC.

For complete specifications and prices of off-the-shelf kits of TRI-PLATE semiconductor mounts and other reliability-proven modules, write today.

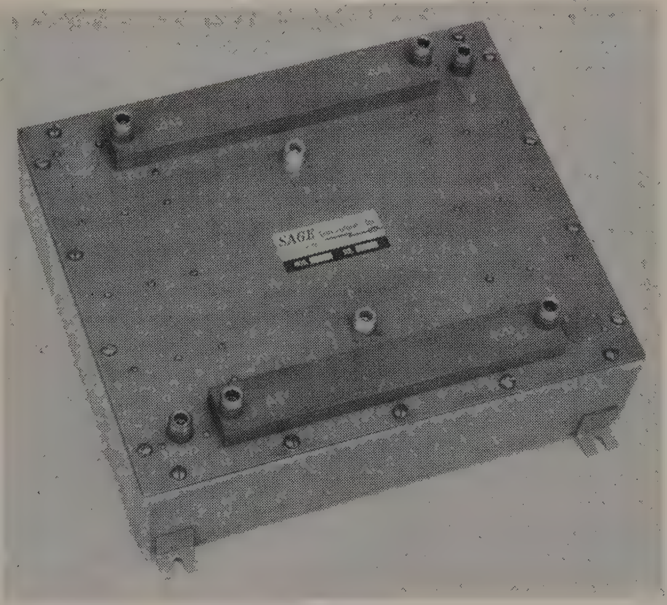
® Sanders Associates, Inc.

Circle Reader Service Card 16

SANDERS ASSOCIATES, INC.

Product Manager, Microwave Products Dept., NASHUA, NEW HAMPSHIRE

"SAGE LABORATORIES HAS DESIGNED MANY INTEGRATED MICROWAVE PACKAGES" . . .



"To whit, the coaxial monopulse antenna feed assembly shown above replaces the conventional rat-race or hybrid ring configuration. The normal operating range is 215 - 260 mc. boresight nulls are 30 db minimum. Antenna output coupling is ±0.1 db; phase is ±5° maximum. VSWR for all ports is 1.2 maximum. The unit weighs 13 lbs. with overall dimensions of 4 7/8" x 11 5/8" x 14".

Sage sub-systems reduce size, lower costs and improve electrical characteristics. May we assist you with your engineering packaging problems?"

SAGE LABORATORIES, INC.
3 Huron Drive • East Natick Industrial Park • Natick, Massachusetts

Industry News

(Continued from page 23)

LOUGHLIN APPOINTED MANAGER AT PRD ELECTRONICS

Raymond G. Loughlin has been appointed manager of the weapons systems division at PRD Electronics, Inc., Brooklyn, N. Y., manufacturer of microwave and electronic instrumentation.

Mr. Loughlin has been employed in the field of microwave and electronic development for nearly 20 years. Prior to joining PRD, he held the position of engineering section head with the Sperry Gyroscope Company, where he was responsible for the development of radar and electronic test equipment for many years.

In 1953 he developed a family of field test sets for the Navy which resulted in a new concept of integrating the functions of several test sets within a single package. His recent activities were in connection with the B-58 Hustler program, wherein he planned and coordinated the test and evaluation of the Automatic Ground Support Equipment.

Mr. Loughlin received the BEE degree from Polytechnic Institute of Brooklyn and during World War II he served in the Navy as an electronic specialist. He is a senior member of the IRE and a member of the PGME and PGEM.

— m w j —

FXR APPOINTS ENGINEERING SECTION HEADS

FXR, Inc., Woodside, N. Y., manufacturer of microwave test instruments and associated high frequency equipment, has appointed Stanley Lehr and Robert E. Othmer as engineering section heads, John Ebert, vice president, microwave division, announced.

Mr. Lehr will work on an expanded program of microwave component and system development, Mr. Ebert said. Mr. Lehr formerly designed microwave components and special test equipment for Doppler Navigators, and earlier was with General Precision Laboratories and The Microwave Research Institute.

A cum laude graduate of the City College of New York, Mr. Lehr holds a master's degree in electrical engineering from Polytechnic Institute of Brooklyn. He is a member of the IRE, Eta Kappa Nu and Sigma Xi engineering societies.

Mr. Othmer will direct development of electronics test equipment for microwave measurement. He did similar work for Narda Microwave Corp., and was before that with Aeroflex Research Corp. and Emerson Radio and Phonograph Corp.

Mr. Othmer's engineering degree is from Pratt Institute. He is a senior member of the IRE and an associate member of AIEE.

— m w j —

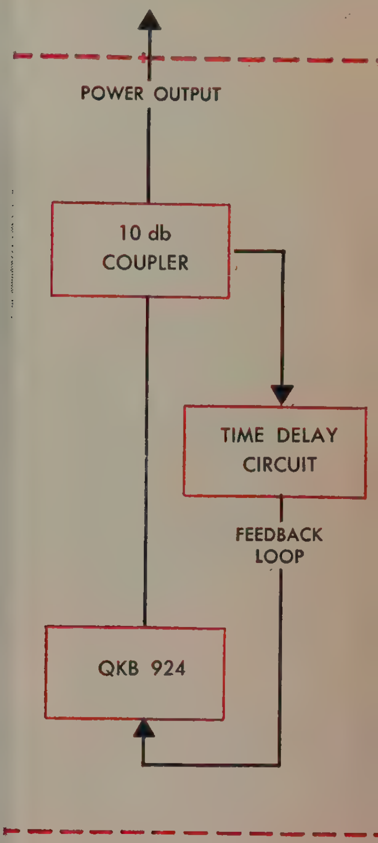
(Continued on page 26)

Circle Reader Service Card 17

QKB 924
RAYTHEON
QKB 924
MADE IN U.S.A.
SERIAL NO.
236

MOPA

STABILIZED OPERATIO

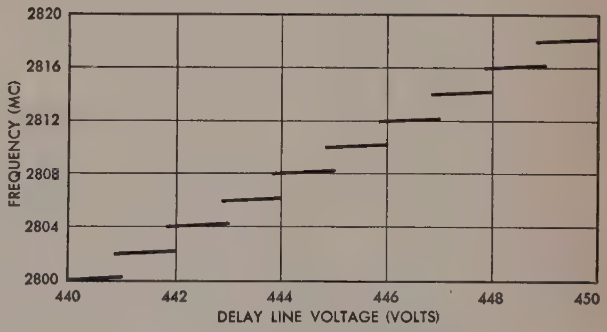


New Raytheon master oscillator assures extreme stability in frequency diversity transmitters

The QKB 924 voltage tunable "O" type backward wave oscillator with the feedback circuit shown above provides a highly stable master driver—local oscillator for S-Band MOPA chains.

External feedback through a delay line provides a 10:1 or more increase in frequency stability—performance that is particularly suitable for frequency diversity MTI applications. The frequency vs. voltage curve of the circuit is essentially flat at discrete steps over the entire 2,700 to 3,200 Mc range. Power output is typically 100 milliwatts with a delay line tuning voltage of 350 to 700 volts. Models are also available at frequencies through X-Band.

Write for detailed application information to Raytheon Company, Microwave & Power Tube Division, Waltham 54, Massachusetts. In Canada: Waterloo, Ontario.



TYPICAL STABILIZED OPERATION

RAYTHEON COMPANY

RAYTHEON

MICROWAVE AND POWER TUBE DIVISION

BOSTON, MASS., BRowning 2-9600 • ENGLEWOOD CLIFFS, N. J., LOwell 7-4911 • BALTIMORE, MD., SOuthfield 1-0450 • CHICAGO, ILL., NAtional 5-4000
DAYTON, OHIO, BAldwin 3-8128 • LOS ANGELES, CALIF., PLymouth 7-3151 • CANADA: Waterloo, Ont., SHerwood 5-6831

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THE LINCOLN LABORATORY
Massachusetts Institute of Technology

Lincoln Laboratory is supplementing its staff. The Laboratory is engaged in basic air defense research for the space age. This expanding program is a natural outgrowth of our advanced research and development in the fields of Radio Physics, Radar, Systems Studies, Satellite Surveillance, Computer Technology and Solid State Physics. Senior scientists are invited to join the Laboratory in solving urgent problems of importance to the defense of the United States.

The Laboratory is seeking qualified specialists in:

RADIO PHYSICS and ASTRONOMY
NEW RADAR TECHNIQUES
SOLID STATE PHYSICS and METALLURGY

- **A more complete description of the Laboratory's work will be sent to you upon request.**

Research and Development
LINCOLN LABORATORY
Massachusetts Institute of Technology
BOX 25
LEXINGTON 73, MASSACHUSETTS

Industry News

(*Continued from page 24*)

HICKMOTT JOINS LENKURT ELECTRIC

George T. Hickmott has joined Lenkurt Electric, San Carlos, Cal., as an engineering placement officer.

He formerly was with Bell Telephone Co. of Canada at Hamilton, Ontario, where he had been a supervisor of terminal maintenance in the Toll department. He started with Bell in 1948 as an installer, later serving as an instructor on loan to the U. S. Air Force for a course in tropospheric scatter radio and channel multiplexing.

He attended the Ryerson Institute of Technology at Toronto.

— *m w j* —

DUNNE NAMED CONTROLLER AT FREQUENCY STANDARDS

Robert P. Dunne has been appointed controller of Frequency Standards, a division of Harvard Industries, Inc., Asbury Park, N. J. He will be responsible for all of the company's financial and accounting activities.

Dunne, who was formerly cost accounting manager for Lockheed Electronics Co., Plainfield, N. J., received the MBA degree in Business Administration from New York University. He also received the BS degree from Rutgers University and taught courses in accounting at the University's evening division.

He is a member of the American Institute of Certified Public Accountants, the National Association of Accountants, the New Jersey Society of Certified Public Accountants, and Beta Gamma Sigma, honorary society in business administration.

— *m w j* —

LUOMA NAMED PHYSICIST AT EMERSON & CUMING

Emerson & Cuming, Inc., Canton, Mass., has announced the appointment of Eino J. Luoma as physicist. In his new position Mr. Luoma will be engaged as project engineer in Research and Development on Microwave Lenses.

Prior to joining Emerson & Cuming, Inc.. Mr. Luoma was associated with Corning Glass Works as senior applications engineer in the Aircraft and Missiles Group of the New Products Division. His principal work was application engineering of pyroceram to radomes. Previously, he spent 16 years with Wright Air Development Division as electronic scientist, with the last 6 years as chief of Radome Development and Design Sections, and the 8 years before that as project engineer on electronic transmission lines.

— *m w j* —

(*Continued on page 30*)

Only the New AIL Type 74

ffers a continuously Tunable (40 to 180 mc) IF Amplifier

for continuous automatic noise figure measurement

Airborne Instruments Laboratory
AUTOMATIC
NOISE FIGURE INDICATOR
TYPE 74
POWER

Adding new versatility to your Automatic Noise Figure Measurement equipment, AIL now offers the outstanding Type 74 Automatic Noise Figure Indicator with a tunable Frequency IF Amplifier...or you can purchase the Tunable IF Amplifier for modification of your present Type 74 equipment.

Single frequency units are also available with greater sensitivity and broader bandwidth.

The AIL Type 74 is designed to permit the adjustment of receiver parameters to minimize noise figure. No special training is required for use on the production line, in the laboratory, or in the field.

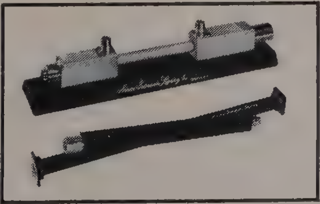
check these high performance features

Noise Figure Range, RF or IF	High range —23 to 36 db with extension to infinity Low range —0 to 25 db
Accuracy	Automatic: Low range ±1/2 db; High range ±1 db Manual: ±0.1 db with AIL Type 30 Attenuator
Automatic Operation	AGC range: 65 db minimum
Manual Operation	Front panel IF gain control
Input Frequency	30 and 40 to 180 mc (tunable); other frequencies available
Sensitivity	100 microvolts
Bandwidth	2.0 mc minimum
Recorder Outputs	Noise figure and AGC

Standard Models Available

Part Number	IF (mc)	Band-Width	Sensitivity	Price
07413	30 (fixed)	6	50	$765
07416	60 (fixed)	6	100	$765
07414	30 & 40 to 180	2	100	$830
07404*	30 & 40 to 180	2	100	$330

*IF Amp. Only



Twelve AIL Type 70 Noise Generators provide continuous coverage from 12 mc to 40,000 mc...most complete line of noise generators available for automatic noise figure measurements.

Write for full information to:

AIRBORNE INSTRUMENTS LABORATORY
DEER PARK, LONG ISLAND, NEW YORK
A DIVISION OF CUTLER-HAMMER INC.

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YOUR CALENDAR OF
MICRO POWER
"no-break"
POWER EVENTS FOR
1961

..by UNITED STATES MOTORS CORPORATION

1ST QUARTER

New BRUSHLESS GENERATORS

U. S. Motors 5 to 20 kw capacity Micro Power units will feature new "brushless" generators to eliminate brush and slip ring maintenance requirements. The no-break units will also operate at plus or minus 1 per cent voltage regulation to satisfy increasing sensitivity of critical operating equipment.

2ND QUARTER

New 5 KW DIESEL MICRO POWER

5 KW capacity "diesel" Micro Power units will be available to fulfill growing demand for a thoroughly dependable power supply unit of smaller capacity.

3RD QUARTER

New LARGER SELECTION

The most complete selection of Micro Power units ever offered will be ready by the second half of '61. Included will be 1½-3 kw gas, or gasoline units — 5, 10, and 15 kw gas, gasoline, or diesel units — 20, 30, 50, 75, 100, 150, 200, and 300 kw capacity diesel units.

4TH QUARTER

New COMBINATION AC/DC UNITS

For the first time, combination AC/DC Micro Power units will be offered in 3 kw and larger capacities with 48 or 129 volt DC current for energizing transistorized microwave communications equipment, and 120/240 volt AC current for handling non-critical power needs.

GROWING STEADILY TO MEET YOUR MOST CRITICAL POWER REQUIREMENTS

1952
First Micro Power Unit.

1953
Intensified design and testing program initiated.

1954
First shipments of 3 KW gas, gasoline Micro Power.

1955
First shipments of 5 KW gas, gasoline Micro Power.

1956
First shipments of 10 KW gas, gasoline Micro Power.

1957
First diesel Micro Power Unit.

1958
Further expansion of research-testing program. First 50 KW Micro Power Unit unveiled.

1959
First shipments of 10 KW diesel Micro Power. 100 KW unit designed.

1960
Over 2000 units in operation. Larger capacities on the way.

authorized sales and service representatives in

CHICAGO, Ill. • DALLAS, Tex. • DENVER, Colo. • DETROIT, Mich. • JACKSONVILLE, Fla.
JERSEY CITY, N. J. • LOS ANGELES, Calif. • PORTLAND, Ore. • SAN FRANCISCO, Calif.

consult the classified section of your phone directory

UNITED STATES MOTORS CORPORATION · MICRO US POWER · OSHKOSH · WISCONSIN

UNITED STATES MOTORS CORPORATION
102 West Fifth Avenue • Oshkosh, Wisconsin

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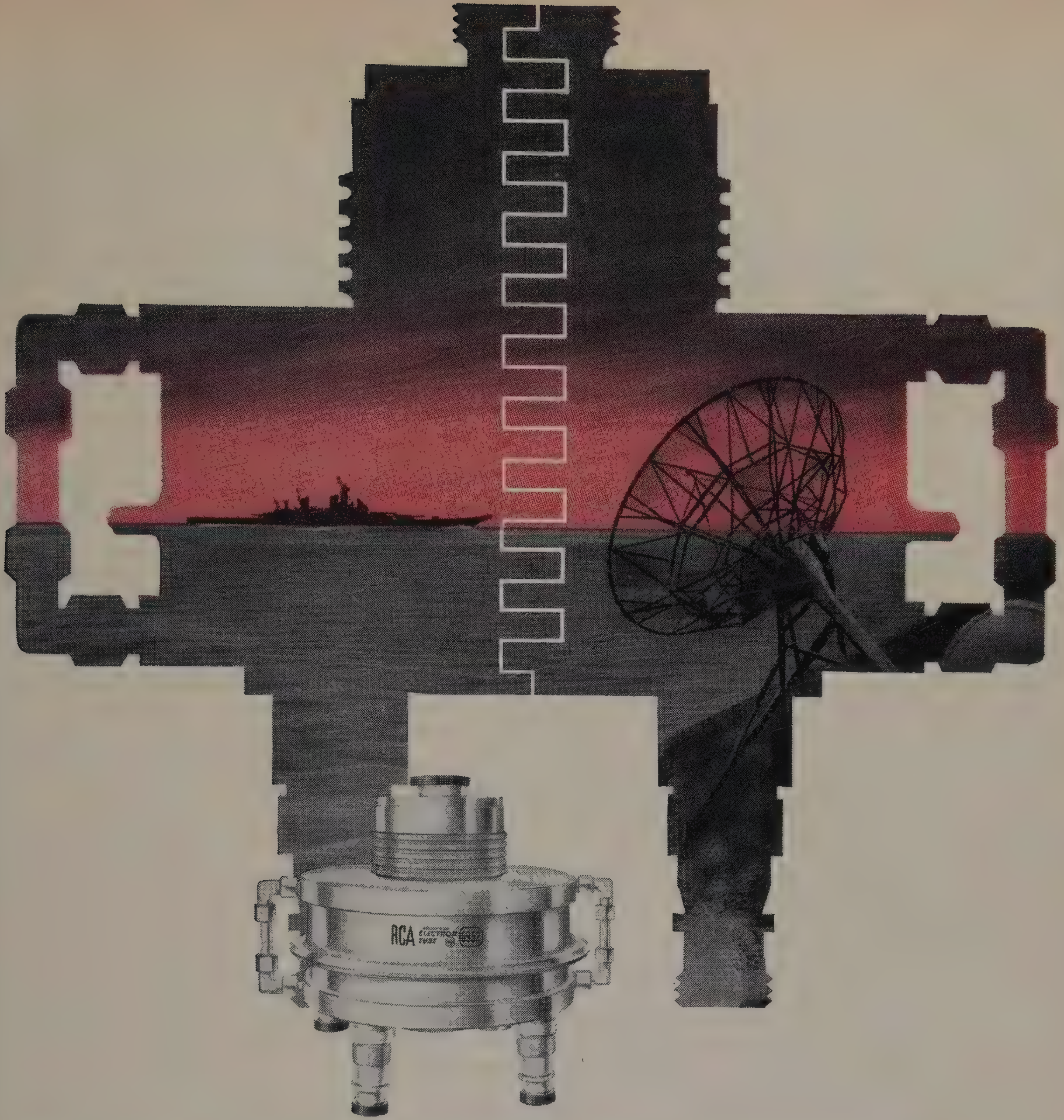

NOW RCA-6952 PACKS TWICE THE PUNCH

:CA announces higher ratings for RCA-6952 Super-
'ower Tube to permit 2 megawatts useful peak power out-
ut. Already proved in sea duty for more than 5000 hours
t the lower ratings, these new, higher ratings are based
n extensive tests. performed under the auspices of the
ureau of Ships, U.S. Navy. Proven life capability at the
ew ratings *is 1000 hours* minimum.

'ariants of the RCA-6952 can be supplied for applica-
ons requiring longer pulse lengths to 2000 microseconds
.higher average power to 20 kilowatts...higher-frequency
peration to 1000 Mc.

For information on the availability of this remarkable Super-Power Tube—and variants tailored for your radar applications—contact your nearest RCA Field Office, or write Marketing Manager, Industrial Tube Products, RCA Electron Tube Division, Lancaster, Pennsylvania.

Typical Operation—RCA-6952

Useful Peak Power Output (megawatts)	Freq. (Mc)	Pulse Length µ sec.	Duty Factor	Power Gain
2	425	13	0.004	100

ATTENTION, DESIGNERS: For a complete technical bulletin on RCA-6952, write RCA, Commercial Engineering, SectionB-101-Q, Harrison, N. J.

CA ELECTRON TUBE DIVISION FIELD OFFICES . . . Industrial Products Sales: Detroit 2, Michigan, 714 New Center Building, TRinity 5-5600 • NEWARK
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RCA

The Most Trusted Name in Electronics
RADIO CORPORATION OF AMERICA

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TWINS FROM
TRANSCO

L-BAND BLADE AND FLUSH ANTENNAS

Identical in all but shape and weight, the AT-741/A blade type, and AT-740/A flush mounted antennas cover 960 to 1220 MC for IFF-TACAN. VSWR is less than 1.5. Units have nominal impedance of 50 ohms, and are vertically polarized. BNC probe is approximately 13 db down. HN connectors are standard. Blade antenna weighs 6.4 oz. Flush mounted unit weighs 12 oz. Write for full details concerning these new L-Band twins and the full line of Transco airborne antennas. Transco Products, Incorporated, 12210 Nebraska Avenue, Los Angeles, California. Phone: BR. 2-5687.

TRANSCO

COAXIAL SWITCHES • WAVEGUIDE SWITCHES • ANTENNAS • MICROWAVE COMPONENTS VALVES • ACTUAT

Industry News

(*Continued from page 26*)

NOWACK JOINS MICRO GEE PRODUCTS

Bert McFadden, president of Micro Gee Products, Inc., Culver City, Cal., has announced the appointment of Robert W. Nowack as manager of Engineering Sales. The appointment is in keeping with Micro Gee's policy of expansion in the field of electronic servo controllers and process controls, made possible by its recent association with Menasco Manufacturing Company and Security Valve Company.

Nowack was formerly sales manager of Metrolog Corp., Pasadena, Cal. In his new capacity, Nowack will be responsible for sales engineering and customer relations. His primary activity will be application engineering of Micro Gee test equipment for automatic guidance and control systems and associated sensors.

Nowack is a graduate of Case Institute of Technology with a BSEE degree and has had five years engineering experience in servo and associated fields.

— *m w j* —

ELECTRONIC SPECIALTY ANNOUNCES APPOINTMENTS

Announcement of several key appointments has been made by James R. Nye, general manager of the Technicraft Division of Electronic Specialty Co., Thomaston, Conn. These appointments reflect the coordination of an extensive new product development and sales campaign now under way by the Technicraft Division.

John Stinson has assumed the duties of Sales Manager of the Division with full responsibility for sales in the United States and Canada. Mr. Stinson has been with Technicraft since June 1957 and prior to this appointment was Assistant Sales Manager.

Elmer A. Sticco, controller of the Technicraft Division, has been appointed Assistant General Manager. Formerly with Peat, Marwick & Mitchell, Auditors, Mr. Sticco, CPA, joined Technicraft in September 1959 as Assistant Controller.

Edward T. Pfund, Jr., has been named Chief Engineer for the Division, placing him in direct charge of a new-produc program in the microwave field. Formerly with Hughes Aircraft Corp. and United Electrodynamics in California, where he managed a number of research and development programs concerned with high frequency communication, he joined Technicraft in March 1960.

The position of Manufacturing Manage has been filled with the appointment of Michael R. Rossi, Jr. Prior to assuming these duties, Mr. Rossi was Plant Superintendent.

— *m w j* —

(*Continued on page 42*)

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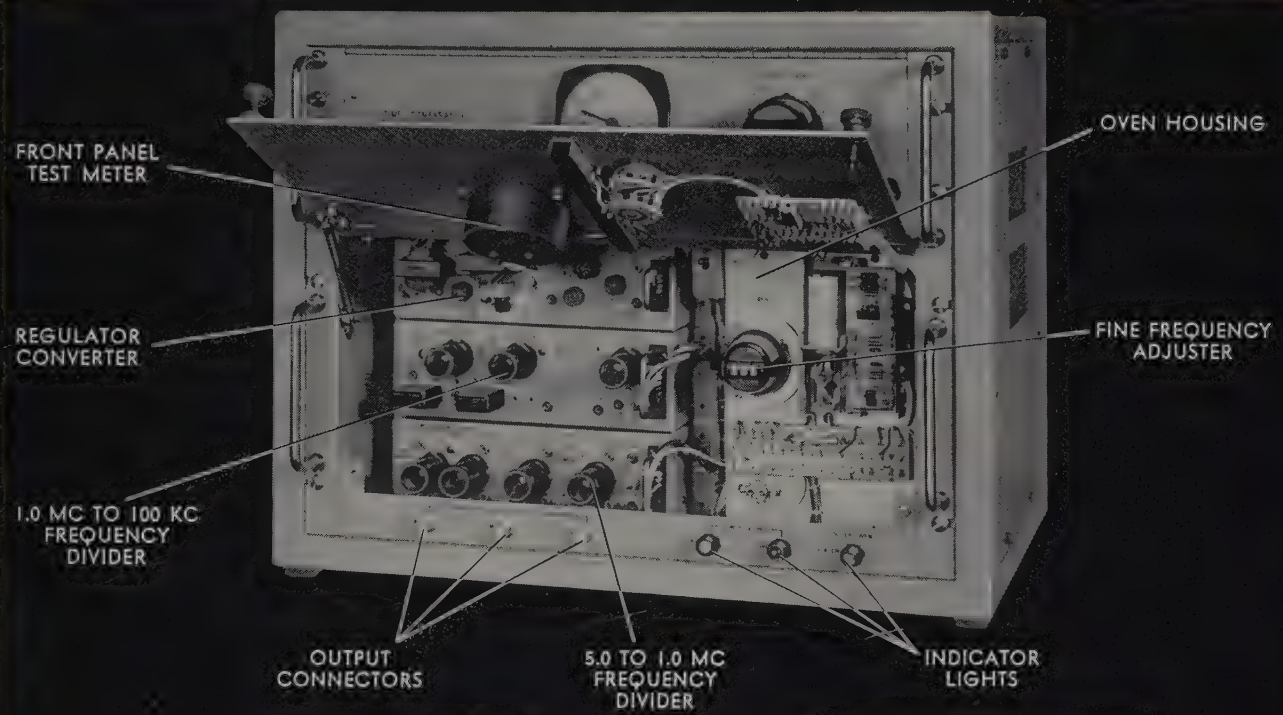
Borg Frequency Standards provide up to 1000 times the accuracy of conventional frequency comparisons

Borg Frequency and Time Standards provide time comparisons of up to 1000 times more accurate than conventional frequency comparisons. With stability of ±5 parts in 10^{10} per day these are the most accurate, most stable frequency standards commercially available. The oscillator is controlled by a 5 megacycle, 5th overtone, AT cut-quartz crystal operating in a modified Pierce circuit. The crystal resonator has an aging coefficient of less than .5 parts in 10^9 per day after 21 days of uninterrupted operation. The standards operate from a 26 ±2 volt D.C. power supply. If D.C. is unavailable, complete power supplies are also available from Borg in both portable and standby models. WRITE FOR COMPLETE DETAILS.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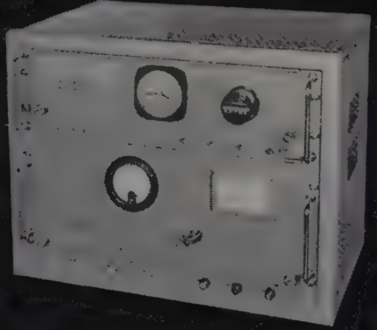
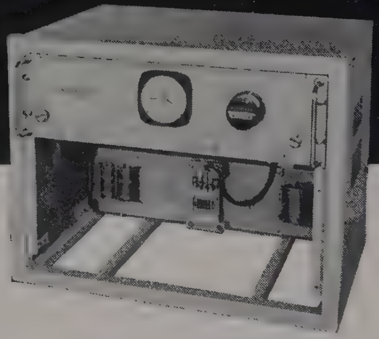


Front panel of standard and time comparator.



Standard with oscillator removed to reveal compact positioning of portable power supply.

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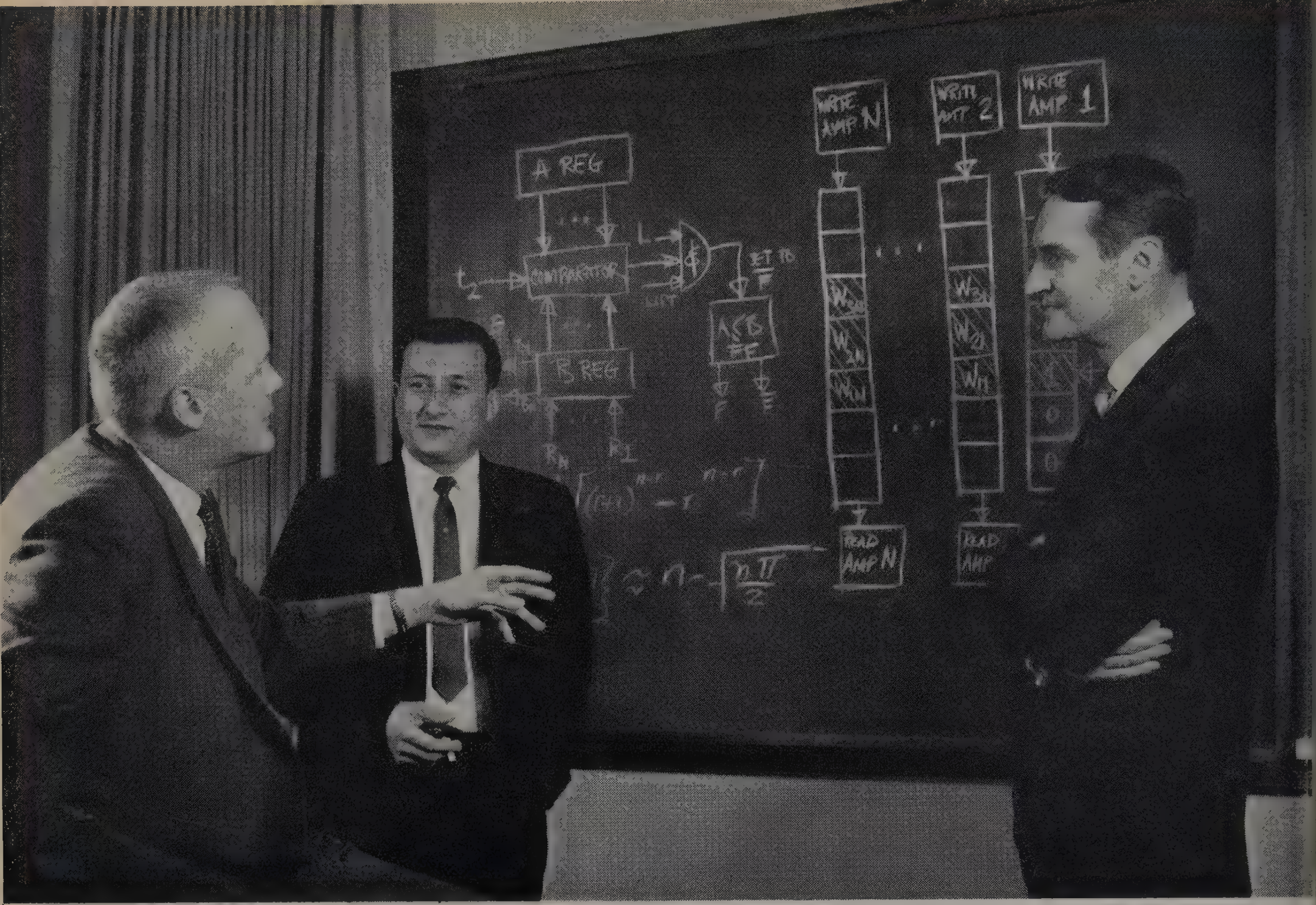

Mr. R. J. Shank, President (right), with Dr. R. E. Fagen (center) anc
Dr. R. B. Dawson (left) of the Information Sciences Division.

A Report from American Systems Incorporated...

A New Organization for Advanced Systems Technology

American Systems Incorporated was launched a year ago for research and development in the electronic systems field. With an across-the-board interest in systems technology, the Corporation has formed five Divisions:

ELECTROMAGNETIC SYSTEMS

Electromagnetic physics; electronic and mechanical scanning antenna systems; development and manufacturing of special microwave components; design, development, and manufacturing of complete sensor systems.

COMMAND AND CONTROL SYSTEMS

Logic of command and control complexes; systems design and development; data acquisition, processing and display; communications.

COMPONENT DEVELOPMENT

Advanced component technology; materials and processes; computer component development; chemical deposition of magnetic materials on drums, disks, rods, tapes.

INFORMATION SCIENCES

Mathematical and statistical research; computer programming, and development of advanced programming systems; computation services; digital system studies; logical design of military and industrial systems; advanced systems analysis.

RESEARCH LABORATORIES

Solid state physics and systems; thin-film research and subsystems; components for information processing.

We are gratified that the past year has been one of significant growth. Operations were started in a leased 10,000-square-foot building. Recently, we moved into our own 27,000-square-foot plant, on a 13-acre site in Hawthorne, California. This plant, which is the first unit in a long-range building program, has custom technical and scientific facilities, including an ultraclean laboratory for thin-film developments and advanced devices research projects.

We are proud that we have been able to attract an outstanding staff of technical people. We believe that scientists and engineers are our primary resource, and it is to utilize this resource that we have founded this corporation. Our operating concept has been to establish an organization which both sought new ideas and provided the facilities in which the creative mind could also be a builder, seeing his ideas through to a practical product.

Qualified scientists and engineers who are interested and experienced in our fields of activity are encouraged to investigate career opportunities with American Systems.

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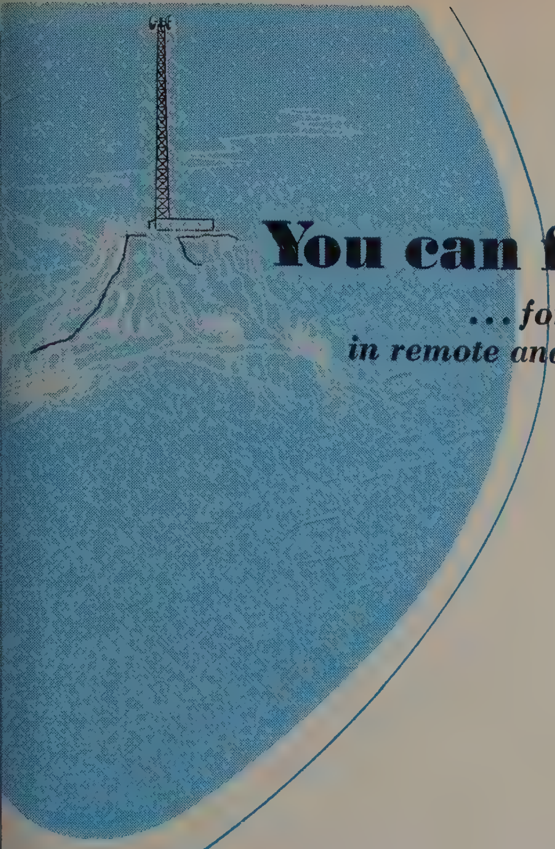

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THE FUTURE
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FREQUENCY RANGE — KMC	A-band 26.5–40	V-band 50–75	E-band 60–90	F-band 90–140	TYPICAL PERFORMANCE FOR A, V and E BANDS	REMARKS
FERIMAT Tunable Isolator	A100	V100	E100	F100*	VSWR 1.25 max – Loss 1.5db max – Isolation 20db min	Operates over full waveguide frequency range
Isolator	A110	V110	E110	F110*	VSWR 1.25—Loss .3db—Isolation 17db min., 25db at center	Bandwidth: 6% A-band, 3% V and E-band Low power Faraday rotation type isolator
On-off Switch or Variable Attenuator	A120	V120	E120	F120*	VSWR 1.25 — Loss 1.5db – Isolation 50db	Low power — approx. 150ma switching current 3μ sec. rise time
Modulator	A130	V130	E130	F130*	4% Band – VSWR 1.25 — Loss on 1.5db – off 30db	Normally closed — approx. 150 ma switching current 3μ sec. rise time
Reciprocal Switch	A140	V140	E140	F140*	3% Band – VSWR 1.25 – Loss 1db — Isolation 20db	High power — approx. 150ma switching current 3μ sec. rise time
Y-Circulator	A150	V150	E150	F150*	VSWR 1.35 – Loss 2db – Isolation 35db	Three port spot tuned for narrow band operation
Four Port Circulator	A160	V160	E160	F160*	3% Band — VSWR 1.3 — Loss 1db — Isolation 20db	Utilizes two dual mode transducers and Faraday rotator

*Under development

TRG INC., ANTENNA & MICROWAVE DEPT., 9 UNION SQUARE, SOMERVILLE, MASS. PHONE: MOnument 6-8680

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". . . THE NUMBER OF MICROWAVE APPLICATIONS IS INCREASING RAPIDLY."

THE MICROWAVE EQUIPMENT MARKET

JAMES C. MUNGER
MANAGER OF PRODUCT PLANNING

SYLVANIA MICROWAVE DEVICE OPERATIONS
Mountain View • California

The total business of researching, designing, manufacturing and marketing microwave equipments is one of the largest within the electronics industry. It is estimated that over 1 1/2 billion dollars will be spent during 1960 for microwave equipment in the United States, of which over 90 per cent is for the military establishment. This business represents about 15 per cent of all electronic equipment sold.

Some Definitions

A microwave equipment may be defined as a combination of circuits and components which employs microwave energy to perform a useful function for its ultimate user. The term microwave energy commonly means short-wavelength electrical oscillations; the microwave wavelengths are usually defined as ranging from 30 centimeters (1000 Mc) to 1 millimeter (300,000 Mc). The useful functions performed by these microwave systems include communications, navigation, target detection, weapons control, and many others.

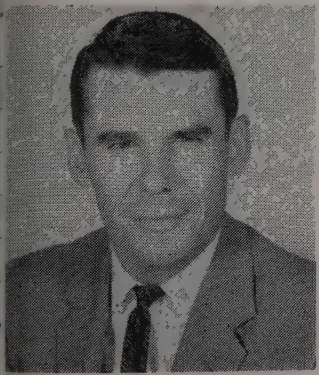
Why Microwaves?

Before outlining the individual microwave equipment types that make up this large market, it might be worthwhile to note briefly those properties of microwaves which make their use valuable to systems designers and users. With a few exceptions, microwave systems rely on the radiation of microwave signals through space. In other words, the microwave energy is used as a transmission medium. But why use such short wavelength signals? What can be accomplished with microwave frequencies that is impossible or more difficult with longer wavelengths?

Those properties of microwaves most often exploited in systems today are described below:

1. The use of microwave energy for transmission through space greatly increases the usable frequency spectrum. Therefore, more radio services can be accommodated by the always crowded radio frequency bands. To use microwaves merely because they exist is not by itself a valid reason for application. However, in many instances only microwave frequencies are available for allocation to new radio services or expansions of existing services.
2. The short wavelength of microwaves permits the formation and radiation of narrow beams of energy with relatively small antennas. This beam concentration also results in high effective radiated power. These high power narrow beams are especially valuable for angular measurement by radar sets. Of course, narrow beams can be formed by frequencies below the microwave region, but the necessary increase in antenna size can prohibit their application in environments where space or weight are limited.
3. The use of microwaves as a transmission medium allows modulation by very wide bandwidth intelligence. Low distortion, efficient modulation is more easily attainable when the equivalent modulation frequency (from either frequency, amplitude or pulse modulation techniques) is a small percentage of the carrier frequency. This wide bandwidth capability is put to use in high capacity communications systems and in high resolution radar systems.
4. Microwave frequencies are relatively free from noise disturbances generated by man-made, atmospheric and cosmic sources. This property is

(*Continued on page 36*)



JAMES C. MUNGER was born in San Jose, California on June 24, 1927. He received the BS and MS degrees in electrical engineering from Stanford University in 1949 and 1950, respectively.

Mr. Munger joined Sylvania Electric Products Inc. at Emporium, Pa. in 1950 where he was a member of the Receiving Tube Applications Department. From 1952 to 1959 he was sales engineer handling sales of all types of Sylvania tubes to equipment manufacturers

From 1959 to the present Mr. Munger has been manager of Product Planning for Microwave Device Operations of Sylvania Electric Products in Mountain View, California.

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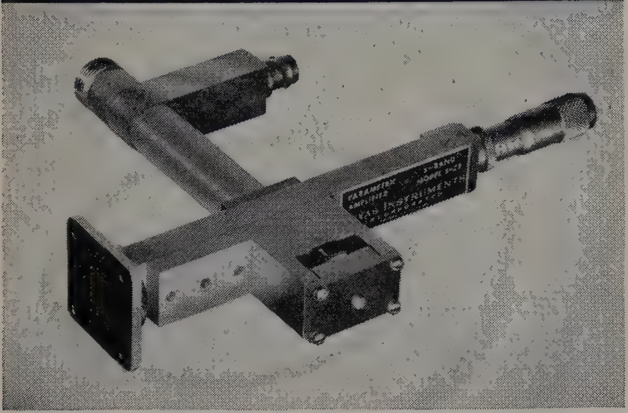

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TYPICAL MODEL S-22 SERIES SPECIFICATIONS	
frequency	2.8 to 2.96 Gc
bandwidth	40 mc
gain	15 db
noise figure (includes circulator loss)	3 db
pump frequency	X band
diode	Texas Instruments XD-500 $F_c \geqq 70$ kmc at –2 v bias
temperature range	–40°C to + 50°C
vibration.	per MIL-E-5400D
pump power	50 mw

For details on TI's S-band amplifiers, write for Bulletin No. DLA-1217. For information on specific applications at all frequencies, contact MARKETING DEPARTMENT.

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MUNGER

(*Continued from page 35*)

exploited, for example, in space communication systems.

The choice of microwave frequencies for specific applications usually results from the consideration of several of the above properties.

History

The development of practical microwave systems has taken place, for the most part, within the past twenty years. Although Heinrich Hertz was able to generate near-microwave frequencies(as high as 500 Mc) in the 1880's, early interest in electromagnetic waves turned to very long wavelengths for application. This was because long wavelength signals propagated well, and, therefore were ideal for long-range radio communication. As the radio spectrum became crowded, higher and higher frequency "short waves" were explored and ultimately used. By the beginning of World War II, techniques and components were available to build practical systems up to about 500 Mc.

However, microwave component and technique development in the 1930's was preparing the way for the rapid system exploitation of microwaves in the 1940's. Especially significant were the developments of the klystron, the magnetron and waveguide. Until the end of World War II microwave system development was dominated by the needs of military radar. The end of the war caused a drastically curtailed military program in microwave systems. However, the Korean War reactivated military spending in microwave development, especially in the fields of high power air search radar, missile control systems, and electronic countermeasures. A tremendous military effort continues to this day. Commercial applications for microwaves since the war have been principally in the areas of microwave communications, aircraft navigation — aids and aircraft traffic-control systems.

Present Market

A functional breakdown of existing microwave systems appears in the accompanying chart. In this outline the various equipments are classed as weapon control, detection/identification, countermeasures, navigation aid, communication, instrumentation, meteorological or miscellaneous systems.

The weapon control category has represented the largest single dollar market for microwave systems during the past several years. Almost all military fighter and bomber aircraft carry microwave fire control radar for the direction of guns and air-air missiles such as Sparrow and Falcon. Also many operational surface-air missile systems such as Nike, Terrier, Hawk and Talos employ microwave radar for guidance. Thousands of radar-guided missiles have been manufactured with each carrying a beacon or transponder so that accurate radar tracking can be maintained for long distances. Although a very classified subject, it is known that thousands of guided missile proximity fuzes have been produced which operate in the microwave region.

The second largest microwave systems category in sales dollars has been that of detection and identification systems. Airborne surface search radar types include high

(*Continued on page 38*)

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Sym:	Parameter	Test Conditions	AP-1	AP-2	AP-3	AP-4	AP-5	AP-6	Unit
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C_T*	Total Capacitance	V=0, f=lmc	.5 to 1.5 for Entire Series						$\mu\mu f$
Q**	Figure of Merit	V_R=2v, f=10 kmc	6 min	7 min	9 min	11 min	13 min	15 min	
f_{co}	Cut-off Frequency	V_R=2v	60 min	70 min	90 min	110 min	130 min	150 min	kmc

*Case Capacitance is 0.4 $\mu\mu f$ nominal

**$Q = X/R = \frac{1}{\omega C_j R_s}$ where C_j is the junction capacitance measured at −2.0 volts

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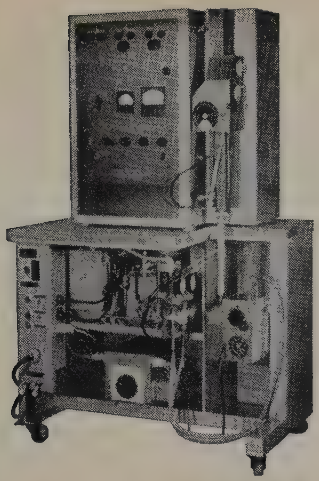

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(*Continued from page 36*)

resolution mapping, submarine detection and bombing/navigation radar. All classes of ships carry surface search radar for harbor navigation and collision avoidance purposes. A relatively new application is battlefield surveillance using ground based surface search radar. Other specialized surface radars include velocity measuring and anti-intrusion types. High power air search radar is employed by the military to detect and track enemy aircraft and missiles. The armed forces have these radars dispersed for continental, tactical and ship defense. The FAA continuously monitors the enroute position of commercial and military aircraft with air search radar. The use of military radar automatically created the need for an electronic identification technique to distinguish between enemy and friendly targets. The resultant Identification of Friend or Foe (IFF) systems employ microwave transponder techniques and are now produced for ground-air, air-air, and ground-ground applications.

The third largest microwave systems market has been that for electronic countermeasures (ECM) equipment. This market segment includes wide bandwidth, rapidly tuable surveillance receivers which detect and analyze enemy electromagnetic radiation from all sources. These receivers have both strategic and tactical applications. When enemy signals are found, jamming transmitters of many types can be used to counter enemy communications, detection radar, fire control radar and fuzes. Newer, more sophisticated ECM devices employ repeater or transponder techniques in which the transmitter output is triggered by or is some function of the received enemy signal.

Navigation aid systems for aircraft represent the fourth important market for microwave equipment. Airborne devices include radar altimeters which are especially useful for precise altitude measurement close to the ground. Doppler radar contributes to air navigation by measuring aircraft ground speed and drift angle. Airborne weather radar devices enables pilots to detect and avoid turbulent storms. At the airport site precision landing radar is used to position accurately incoming aircraft so that landings in adverse weather can be effected. Examples of these landing aids are the Ground Controlled Approach (GCA) and the FAA Precision Approach Radar (PAR) systems. The TACAN air navigation system enables a pilot to determine his angular position and range from a known ground station. TACAN uses transponder techniques in the microwave region. To help air traffic control around an airport many airplanes now carry radar beacons so that ground radar can easily detect and identify them.

Communications is the fifth largest microwave equipment market. At present the most important segment of this business is the line-of-sight radio relay market. A wide range of government, common carrier, utility and industrial organizations use this low power transmission medium to carry all types of intelligence. Because of their wide bandwidth capability these systems can carry TV, radar video and digital data as well as hundreds of multiplexed telephone or telegraph messages. The other microwave communication business is an over-the-horizon radio

(*Continued on page 40*)

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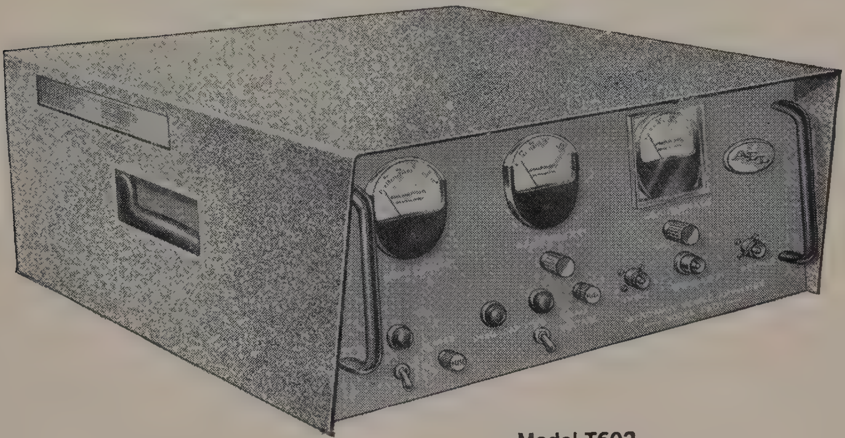

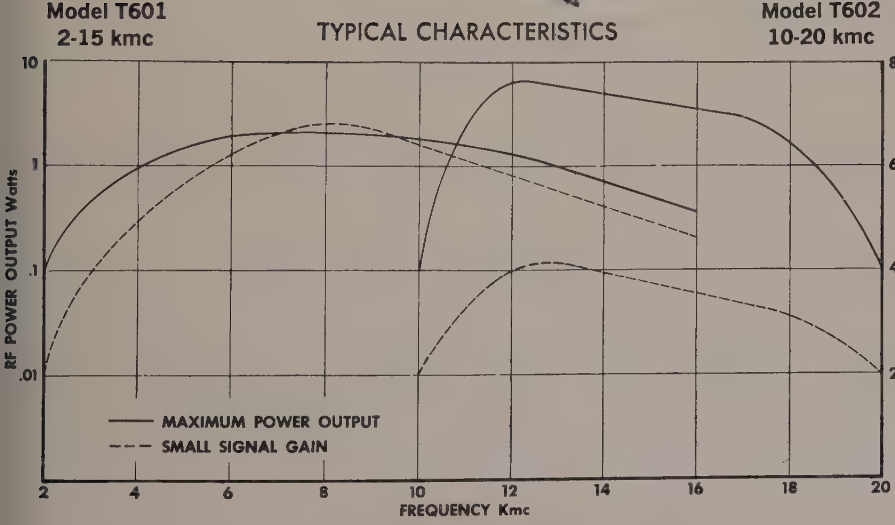

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Functional Outline of Existing Microwave Systems

A — Weapon Control Systems
1. Weapon (Fire) Control Radar
2. Missile Guidance Receiver
3. Missile Homing Radar
4. Missile Fuze
5. Missile Beacon

B — Detection and Identification Systems
1. Surface Search Radar
2. Air Search Radar
3. IFF

C — Electronic Countermeasures
1. Surveillance Receiver
2. Jamming Transmitter
3. Transponder/Repeater

D — Navigation Aid Systems
1. Doppler Navigation Radar
2. Aircraft Landing Radar
3. Radar Altimeter
4. TACAN
5. Weather Avoidance Radar
6. Radar Beacon

E — Communication Systems
1. Line-of-Sight-Radio
2. Over-the-Horizon Radio

F — Instrumentation Systems
1. Tracking Radar
2. Radar Beacon
3. Test Instruments

G — Meteorological Systems
1. Weather Detection Radar
2. Radiosonde

H — Miscellaneous Systems
1. Cooking ranges
2. Radio Astronomy
3. Particle Acceleration
4. Spectograph

MUNGER

(*Continued from page 38*)

technique called tropospheric scatter. These high power systems allow single transmission hops in excess of 100 miles and are especially useful for reliable communications over water and rugged terrain.

Instrumentation is another important category in the microwave equipment market. On guided missile test ranges the positions of test missiles and target drones are precisely monitored by ground tracking radar. The missiles and drones themselves often carry radar beacons so that the ground radars can track for longer distance. Many types of microwave test instruments are manufactured for use by the electronic and other industries. These instruments include signal generators, wide-band laboratory amplifiers, spectrum analyzers and field strength receivers. Also, many test instruments are often combined into custom instrumentation systems for use as field check-out equipment.

Another application for microwave systems is in the field of meteorology. Ground weather radars are being employed more and more to detect, evaluate and track tornados, hurricanes and other storms. Radars are also used to measure rainfall and wind velocity. Microwave radiosonde systems detect and report meteorological conditions in the atmosphere. Sensors are sent into atmosphere on balloons or rockets and the collected data is transmitted to the ground via a microwave radio link.

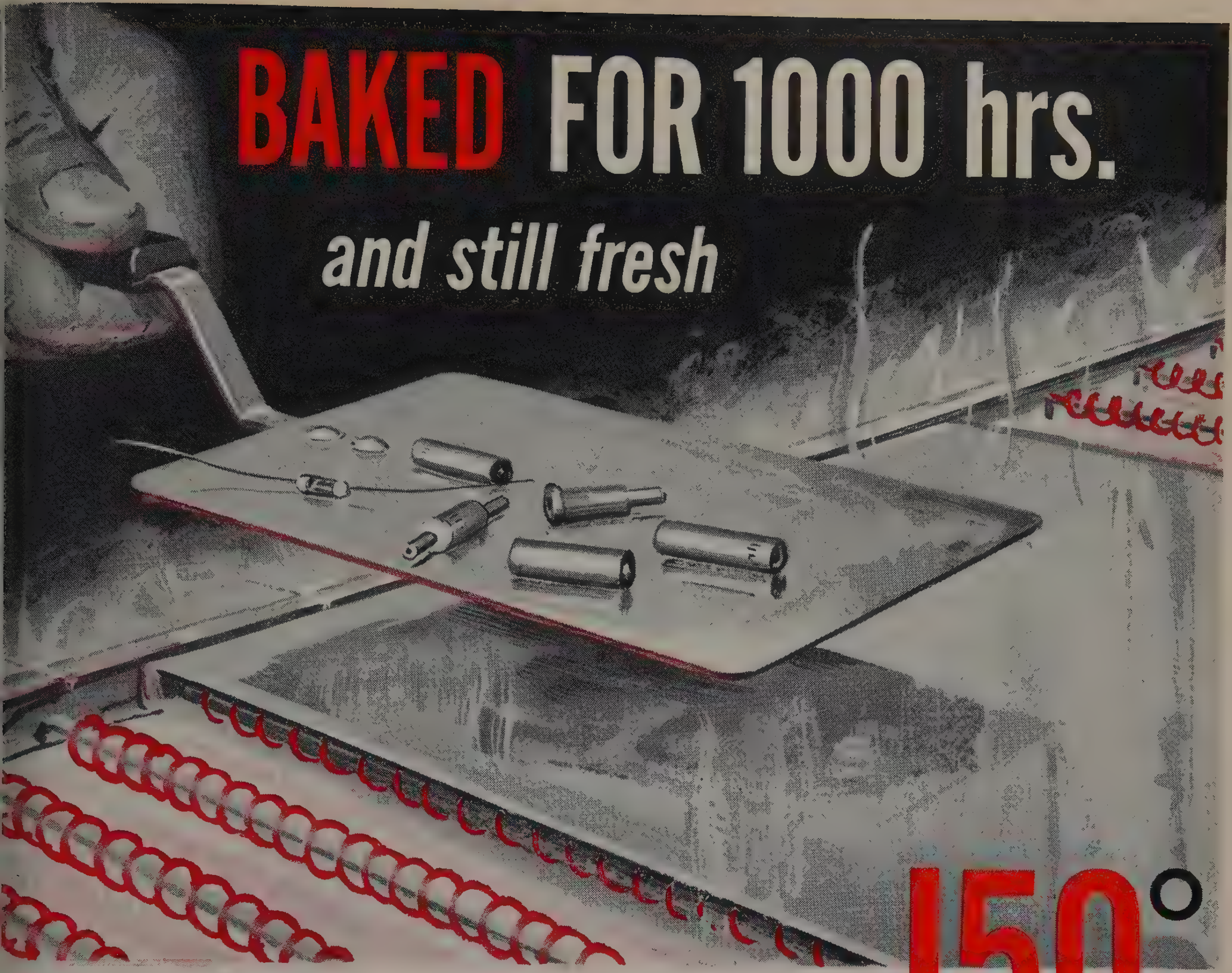
Many other applications have been found for microwaves which do not fit into the previous categories. Relatively high average power microwaves are used for cooking purposes. Radio astronomy equipment, some types of particle accelerators and microwave spectrographs are employed as research tools. While the above list of microwave applications is not absolutely complete, it does describe most of the important uses in existence today.

Future

The use of microwaves in the above applications i well established and it is likely that these equipment type will remain active for many years. Of course, the relativ economic importance of each will probably change in th coming years.

But what are the future applications for microwaves Many important future uses are hidden by governmen security restrictions and many are still in the brains o imaginative scientists and engineers. However, it is possi ble to name a few future equipments which are now i the experimental or prototype stage. In the category o detection systems, microwave anti-collision devices fo aircraft and automobiles are being investigated. Terrai avoidance radar for low flying aircraft promises to grow into an important business. Aircraft all-weather landin systems using microwaves are being tested today. I communications, microwave links with satellite repeater are in the hardware stage. Communication with milli meter wavelength signals is being explored by industr and the military. Telemetry systems will move from VHI to the microwave region within the next few years. Ex ploitation of microwaves for heating and processing i expected to expand greatly in the future. It is apparen that the number of microwave applications is increasin rapidly.

The total electronic equipment business is expected t increase by about 50 per cent in the next five years. Bu by how much will the microwave equipment segment o this market grow in the same period? This question i very difficult to answer because of a constantly changin technology and the extreme dependence of the microwav business on the military budget. An educated guess woul indicate that microwave systems will enjoy approximatel a constant percentage of the total electronics busines for the next several years.



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1N21C, D, E, F
1N21WE
1N23C, D, E, F
1N23WE
1N26B
1N26C
D-4136*
1N53D
D-4082*
1N78C
1N78D
1N31A
1N415C, D, E, F
1N416C, D, E, F
1N630
1N1610
1N830, A
1N831, A
1N832
1N833
1N918
1N1611A
D-4075
D-4110
D-4140
D-4141

*D-4136 A, B, C—Hi-temp 1N53A, B, C
*D-4082A, B—Hi-temp version of 1N78A, 1N78B

SYLVANIA

Subsidiary of **GENERAL TELEPHONE & ELECTRONICS**

(*Continued from page 30*)

ANTENNA SYSTEMS ANNOUNCES NEW APPOINTMENT

Antenna Systems, Inc., Hingham, Mass., has announced that Merle C. Sherman has been appointed financial vice president and has also been elected to the board of directors.

Mr. Sherman has been associated with the antenna industry for many years, and prior to joining ASI was treasurer of D. S. Kennedy & Co. He is a member of the National Association of Accountants.

—*mwj*—

MEGADYNE ELECTRONICS, CWS WAVEGUIDE MERGER RATIFIED BY STOCKHOLDERS

The stockholders of Megadyne Electronics, Inc. have voted to approve the merger with CWS Waveguide Corp., it was announced by Robert A. Vogeler, Megadyne's president. The shareholders of CWS Waveguide had ratified the proposed merger at their meeting last month.

The name of the new combined company will be Megawave Electronics Corporation. Mr. Vogeler will be president of the new company, and Mr. Oei Ing Bian, now president of CWS Waveguide, will become executive vice president of Megawave.

The merger was effected on the basis of an exchange of common stock on a share-for-share basis.

For the time being, Mr. Vogeler stated, CWS Waveguide and Megadyne Electronics will operate as divisions of Megawave Electronics Corp. Megadyne recently moved into a new 15,000 square foot plant in Danbury, Conn., where its manufacturing operations will be concentrated. CWS Waveguide's plant of 14,000 square feet is at Lindenhurst, Long Island. Eventually, stated Mr. Vogeler, it is planned to consolidate all the operations of Megawave Electronics Corp. in one plant.

—*mwj*—

BALLISTIC MISSILE STUDY AWARDED TO LORAL

A technical study for the development of a new Ballistic Missile Attack Warning System has been undertaken by Loral Electronics Corp., New York, N. Y.

The six month, secret program was awarded by the Air Force's Rome Air Development Center, Air Research and Development Command, Loral said.

Loral, prime contractor, is being supported in the study by an engineering and scientific group of sub-contractors including Arthur D. Little, Inc., Barnes Engineering Co. and Smyth Research Associates.

—*mwj*—

AMERICAN RESEARCH & DEVELOPMENT ELECTS SKIFTER T BOARD OF DIRECTORS

Election of Dr. Hector R. Skifter as member of the board of directors of A

erican Research a Development Cor Boston, Mass., h been announced Georges F. Dori president. Dr. Sk ter is president Airborne Inst ments Laborato a Division of C ler-Hammer, In and also a vi president and director of Cutler-Hamm

Dr. Skifter succeeds Horace S. Fo treasurer emeritus of MIT and a found of American Research and Developme Corp. Mr. Ford will continue to serve a consultant.

Dr. Skifter is presently a member the Scientific Advisory Panel, Departme of the Army, and the Scientific Adviso Committee, Department of Ordnan U. S. Army. He also serves as a consulta to the President's Science Advisory Co mittee, Executive Office of the Preside and to the Director of Defense Resear and Engineering, Department of Defen He has previously served as assista director of Defense Research and Eng neering (Air Defense), DOD, and cha man of the Committee on Air Navigati of the Research and Development Boa DOD. He has been a member of t Technical Advisory Panel on Electroni DOD; Technical Advisory Panel Electronic Countermeasures, DOD; t Gaither Security Resources Panel of t President's Science Advisory Committe consultant to the Assistant Secretary Defense, Research and Development; a consultant to the Air Navigation Boar

—*mwj*—

GE ANNOUNCES MICROWAVE SYSTEM FOR USE BY BUSINESS AND INDUSTRY

General Electric Company, Lynchbu Va., has introduced a new business mic wave product designed to operate in t 12 kMc frequency band.

The new equipment will be added General Electric's existing 2 kMc mic wave lines, providing complete fr quency coverage for business firm planning to make use of new channe allocated by the Federal Communicati Committee for privately-owned trunk li systems.

The equipment accommodates up to 2 private trunk lines for voice, teletype data messages. These are transmitted in frequency band 500 Mc wide betwe 12,200 and 12,700 gigacycles.

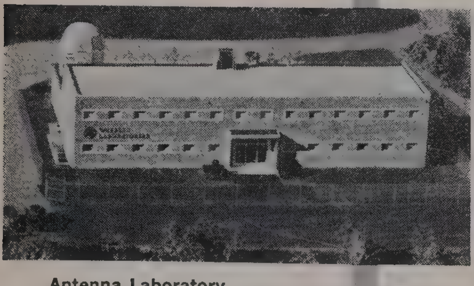
There is no restriction on the type messages allowed by the Federal Co munications Commission under new FC point-to-point communication rules. Pa roll information may be transmitte orders received, service facts or oth business intelligence.

—*mwj*—

(*Continued on page 44*)

WHEELER LABORATORIES, INC.
ON LONG ISLAND/A SUBSIDIARY OF HAZELTINE CORPORATION

Main Office and
Microwave Laboratory
Great Neck, New York



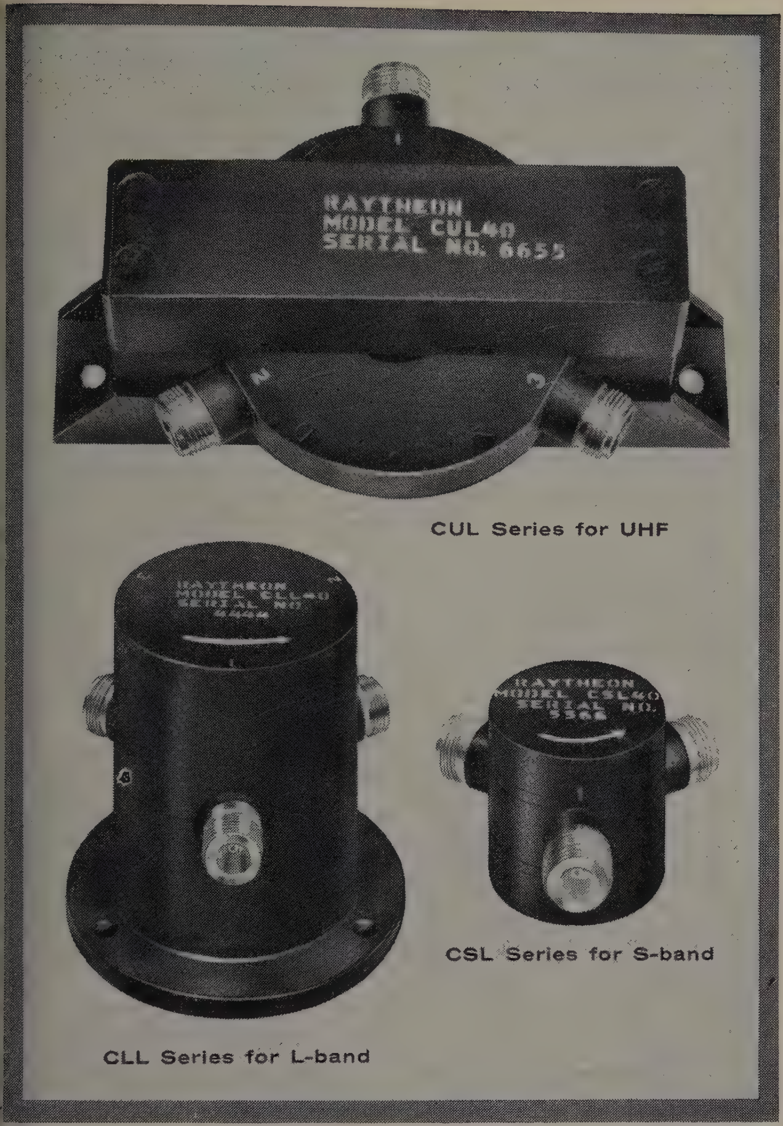
Antenna Laboratory
and Test Range
Smithtown, New York

In the field of microwave engineering, Wheeler Laboratories occupies a unique position as an industrial laboratory devoted exclusively to consulting and development.

As a service to many prominent laboratories and manufacturers, WL designs radar and communication antennas, waveguide components, and microwave assemblies. Your inquiries are invited.

HAROLD A. WHEELER
and Engineering Staff

RECENT RAYTHEON DEVELOPMENTS
N MICROWAVE FERRITE DEVICES



New miniature broadband circulators for UHF, L & S bands

Now, Raytheon introduces compact, lightweight, three-port circulators with extremely low insertion losses

Miniaturized Raytheon coaxial line circulators for UHF, L- and S-bands now are available with isolations of 20 db and insertion losses of .5 db and less!

The L- and S-band units—in production just 14 months after Raytheon announced the first coaxial ferrite circulator to the microwave industry—can be mounted directly to steel structural members without any separation or shielding. Maximum dimensions are 1¾ inches for S-band, 4 inches for L-band and 6⅛ inches for UHF models. A combination of any two of the units can be packaged for a highly efficient 4-port circulator.

To learn more about these significant developments and other circulators now available down to 400 Mc and up to 6000 Mc with similar characteristics, please write, stating your particular area of interest, to the following address: Raytheon Company, Special Microwave Device Operations, Waltham Industrial Park, Waltham 54, Massachusetts. In Canada, contact Raytheon Canada Limited, Waterloo, Ontario.

TYPICAL SPECIFICATIONS OF MINIATURIZED CIRCULATORS

	UHF BAND CUL SERIES	L-BAND CLL SERIES		S-BAND CSL SERIES
Frequency Range	800-1000 Mc	1000-1700 Mc	1700-2400 Mc	2400-4000 Mc
Bandwidth	Any 10% band	Any 10% band	Any 10% band	Any 10% band
Isolation	20 db min. 35 db max.	20 db min. 35 db max.	20 db min. 35 db max.	20 db min. 35 db max.
Insertion Loss	0.3 db min. 0.5 db max.	0.2 db min. 0.4 db max.	0.2 db min. 0.4 db max.	0.2 db min. 0.4 db max.
VSWR	1.25 max.	1.25 max.	1.25 max.	1.25 max.
Power (Average)	5 watts	5 watts	5 watts	5 watts
Power (peak)	5 kw[2]	5 kw[2]	5 kw	5 kw
Weight (max.)	4.8 lbs.	3.3 lbs.	2.3 lbs.	11 oz.
Diameter (max.)[1]	6⅛ in.	2½ in.	2½ in.	1¾ in.
Height	3¼ in.	4 in.	2½ in.	1⅝ in.
Connectors	Type N	Type N	Type N	Type N
Temperature Range[3]	T_0 ±20°C	T_0 ±20°C	−40°C to +60°C	−40°C to +60°C

[1] Excluding Connectors

[2] Up to 100 kw is possible with Type HN connectors

[3] T_0 is 25°C unless otherwise requested

RAYTHEON

RAYTHEON COMPANY
SPECIAL MICROWAVE DEVICE OPERATIONS

Circle Reader Service Card 74

Industry News

(*Continued from page 42*)

TWO JOIN TECHNICAL STAFF AT WATKINS-JOHNSON CO.

Dr. Stanley E. Sobottka and Kurt E. Zublin have joined the technical staff of Watkins - Johnson Co., Palo Alto, Cal.

Dr. Sobottka, a physicist, will be engaged in research and development of a low-noise millimeter-wave traveling-wave tube. He came from Boeing Airplane Co., Seattle, where he investigated the microwave interaction between electron beams and gaseous plasmas.

A native of Wisconsin, Dr. Sobottka received a BS in Physics from the University of Wisconsin and MS and PhD degrees from Stanford University. He held a National Science Foundation fellowship during part of his graduate career at Stanford and as a research assistant in the Physics Department carried out experiments in high-energy electron scattering from carbon and deuterium neuclei.

He is a member of the American Physical Society, Sigma Xi and Phi Beta Kappa.

—*mwj*—

CIRAL JOINS RANTEC MARKETING DEPARTMENT

G. H. Singer, Rantec vice president, has announced that Jerry Ciral has joined Rantec Corp.'s Marketing Department, Calabasas, Cal.

Mr. Ciral's experience is expected to provide additional strength to handle the increased marketing activities associated with the company's continued growth.

Mr. Ciral was formerly with Kittelson Company. His most recent position prior to joining Rantec was General Manager of General Scientific Corp., a Division of the San Fernando Electric Manufacturing Companies.

—*mwj*—

GOLDSTEIN OPENS PUBLIC RELATIONS, COUNSELLING OFFICE

Samuel H. Goldstein, former advertising and public relations director at The W. L. Maxson Corp., multi-plant military electronics company, has established a new public relations and advertising counselling office.

Located at One Northern Boulevard, Great Neck, L. I., N. Y., he will specialize in the planning and development of sales-oriented public relations and advertising programs for the electronics industry.

Mr. Goldstein is a member of the IRE, and the American Ordnance Association. He is active in the IRE Professional Group on Aeronautical and Navigational Electronics and was News Editor of the PGANE Transactions.

—*mwj*—

SPERRY APPOINTS LEUTWILER MARKETING MANAGER

The appointment of John H. Leutwile as marketing manager of the Sperr Microwave Elec tronics Compan Clearwater, Fla. has been announce by Sperry's Div sion Manager E. Venaglia.

Experienced i the fields of ele tronic marketin and engineerin Mr. Leutwiler wi direct all military and commercial sale activities. A division of Sperry Ran Corporation, Sperry Microwave specialize in test and weapon system support instru mentation, microwave components, soli state devices and materials, and microwav and electronic instruments.

Mr. Leutwiler's most recent affiliatio was with the Emerson Electric Compan of St. Louis as director of Market Researc of the E. & A. division. Prior to that h was, for twelve years, vice president of th Missouri Research Labs in St. Loui responsible for sales and operations.

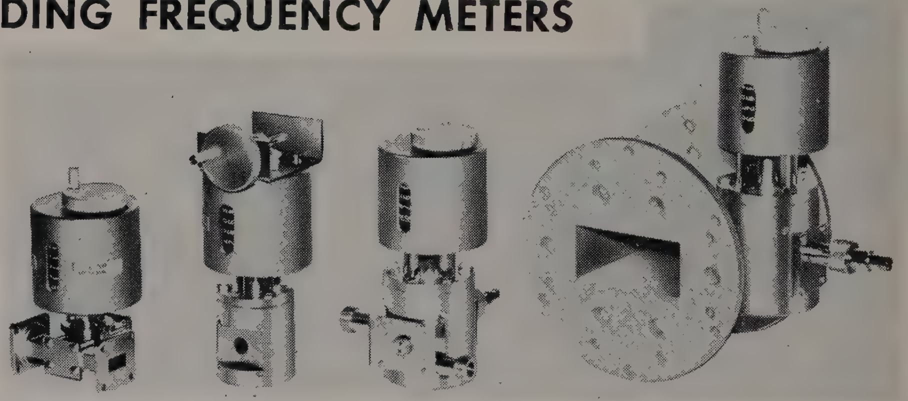
Mr. Leutwiler received his BS degree i engineering administration from Wash ington University in 1941, and began hi professional career as a service enginee with Emerson Electric in 1942.

—*mwj*—

(*Continued on page 75*)

DIRECT READING FREQUENCY METERS

Type No.	Frequency range kMc/s
SL 7510	1,1 — 1,7
SL 5815	1,55 — 2,5
SL 5212	2,5 — 4,0
SL 5590	3,3 — 4,9
SL 5174	3,8 — 5,9
SL 7599	4,5 — 7,29
SL 5585	5,4 — 8,6
SL 7100	7,05 — 11,2
SL 5205	8,2 — 12,4
SL 7095	12,4 — 18,0



The SIVERS LAB Direct Reading Frequency Meters enable a quick and accurate determination of frequencies in the Microwave region. The frequency range from 1 kMc/s to 18 kMc/s is covered by 10 models. Each model operates over the full waveguide band, with direct reading accuracy better than ±0,1%.
Attachments are available to enable the frequency meter to be included in the interior of a rack system with the control on the front panel.
Price example: SL 5205 supplied with end-connected and passing waveguide $165.00 fob Stockholm

By means of the exchangeable coupling elements

- End-connected waveguide or coaxial
- Passing waveguide or coaxial
- Crystal mounts and lid

various circuit arrangements most suitable for the occasion, like reaction, absorption or transmission type of frequency meter can be formed by the user.

Please write for our complete catalogue.

SIVERS LAB

P.O. BOX 42018
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SWEDEN
CABLE: SIVERSLAB

2 NANOSECOND MICROWAVE SWITCHING with SOLID STATE RELIABILITY

MA-3457
MICROWAVE ASSOCIATES

MA 3457
S.P.S.T. C-Band
Solid State Switch

Microwave Associates' new coaxial switches provide:

- Efficient switching across the microwave spectrum
- Solid-state reliability for military applications
- Lightweight (approx. 5 oz.) ruggedized construction
- Low driving power — from 10 to 100 milliwatts
- Power handling capability {4 watts CW (S.P.S.T. unit)
  150 watts peak at 0.001 duty cycle
- Low insertion loss — as low as 0.2 db

Solid-state switches are as good as the semiconductors they incorporate. All units described use the most advanced microwave silicon diodes available, specifically developed for this function by Microwave Associates Semiconductor Division.

LOW POWER LEVEL COAXIAL SWITCHES

Frequency (Mc)	Insertion Loss (Max)	Isolation (Min)	Switching Power
210-240	0.2 db	20 db	10 mw
260-340	0.2 db	18 db	10 mw
400-500	0.3 db	20 db	10 mw
570-630	0.3 db	20 db	10 mw
900-1000	0.3 db	20 db	10 mw
1250-1350	0.5 db	20 db	10 mw

MEDIUM POWER LEVEL COAXIAL SWITCHES

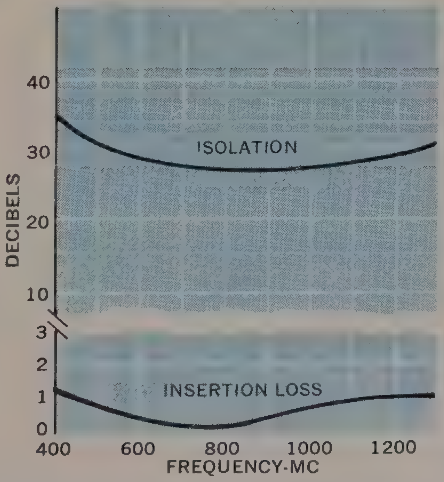
Frequency (Mc)	Insertion Loss (Max)	Isolation (Min)	Switching Power
200-1000	1.5 db	22 db	70 mw
1000-2000	1.5 db	20 db	70 mw
2000-4000	2.0 db	16 db	70 mw

LOW POWER LEVEL VOLTAGE VARIABLE ATTENUATORS

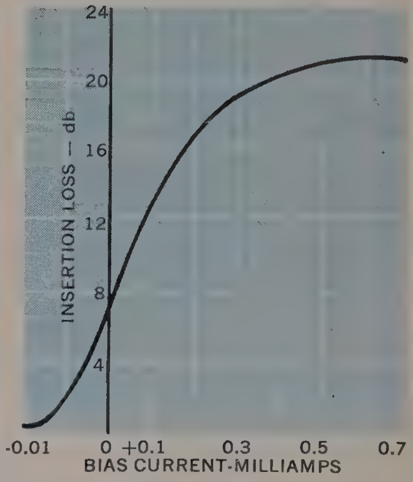
Frequency (Mc)	Attenuation Range
260-340	0.2 db-18 db
400-450	0.3 db-20 db
570-630	0.3 db-20 db
1250-1350	0.5 db-20 db

arrow-band higher frequency units are available with lower
ss and increased isolation.

TYPICAL PERFORMANCE
BROADBAND MICROWAVE
SWITCH SPST



TYPICAL PERFORMANCE
VOLTAGE VARIABLE ATTENUATOR
(425 Mc±25)

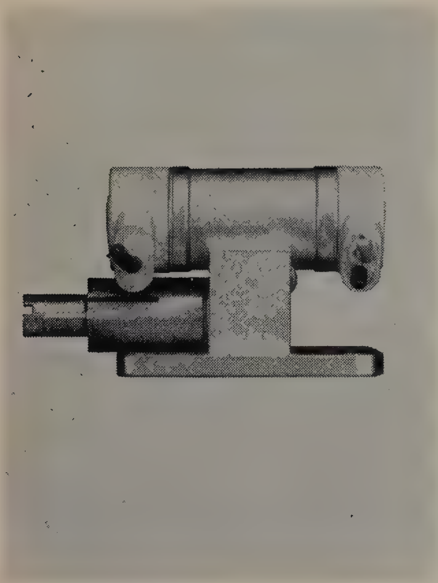


Units for handling higher powers are now in development. Microwave Associates has capabilities for meeting your requirements for single-pole multiple-throw and waveguide switching devices. Our switches invite comparison. We invite your inquiries. A quotation/data sheet will be sent on request.

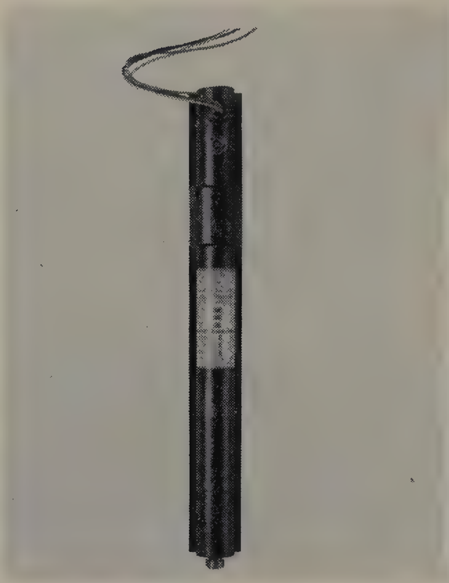
MICROWAVE ASSOCIATES, INC.
ELECTRON TUBE AND DEVICE DIVISION, Burlington, Mass.
Western Union FAX • TWX: Burlington, Mass., 942 • BRowning 2-3000

Circle Reader Service Card 32

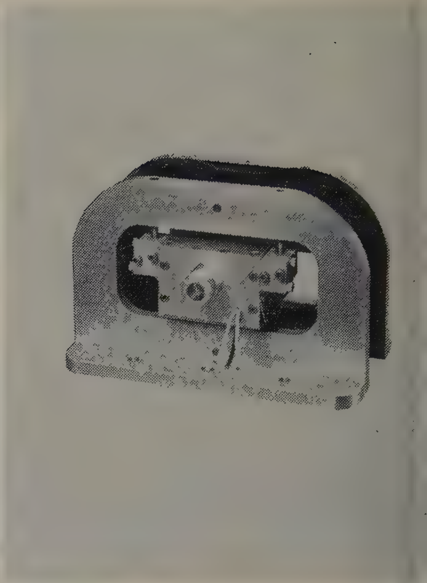
here today:



Eimac 1K20 Series
Reflex Klystrons
Tuning Range: 8.5 to 11.5 kMc
Typical Output: 75 mW



Eimac X778 TWT
Frequency: 5.0 to 11.0 kMc
Small Signal Gain: 60db
Minimum Power Output: 1 watt



Eimac X-747 Voltage-Tunable Magnetron
Tuning Range: 400 to 1200 Mc
Nominal Power Output: 100 mW

here tomorrow:

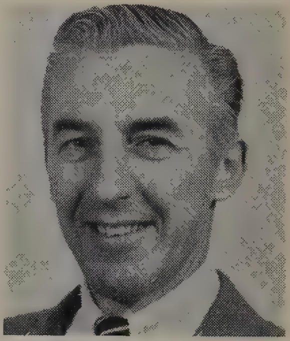
New Eimac X- and K-band one watt reflex klystrons with excellent stability and low-noise characteristics.

New Eimac higher powered TWT's to meet the requirements of commercial and military applications.

New Eimac S-band Voltage-Tunable Magnetrons retaining desirable L-band linearity and long life.

And there's more to come! Behind the scenes a fully staffed Eimac Microwave Laborator offers the broadest possible capabilities for new tube development. You'll find the most advanced answers to your microwave needs in Eimac . . . world leader in negative grid tubes, microwave tubes, amplifier klystrons. Write: Microwave Products, Eitel-McCullough, Inc., San Carlos, California.

CONTRIBUTORS IN THIS ISSUE



WILLIAM P. ERNST was born in New York City in 1922. He attended the Newark College of Engineering (Evening School) receiving a BS degree in Electrical Engineering in 1957. In addi-ion, he did graduate work at N.C.E. and Rutgers, the State University.

Mr. Ernst has been a junior engineer (1948-50) at La Vole Labs, project engineer (1950-53) t Chatham Electronics, resident engineer (1953-59) at Bell Telephone Labs, Stavid Eng. Field Division. Presently he is on the Project Staff, Engineering, at Princeton University.

He is a member of IRE and PGMTT.

F. BERINGER FANK received the BSEE degree in 1950, the MSEE degree in 1951, and his PhD degree in 1958, all from Stanford University.

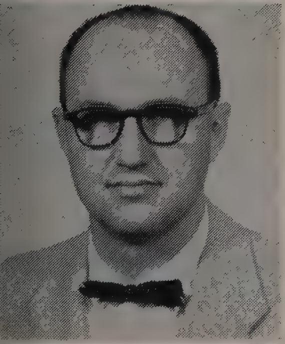
During World War II, he was assigned to the Naval Materiel School and served as an electronics technician. As a first year graduate student, he worked as a Research Assistant on a project investigating radio reflections from meteor trails.

Dr. Fank joined General Electric Company in 1951 as a Test Engineer. Upon completion of his Engineering Training Program assignment, he accepted a position in the Electronics Laboratory where he spent the next two years working on the development of broadband microwave tuning devices. In 1954, he transferred to the General Electric Microwave Laboratory where he also enrolled in the Honors Cooperative Program at Stanford University and subsquently completed work for his doctorate.

Dr. Fank's experience at the General Electric Microwave Laboratory has been mainly with low and medium power traveling-wave tubes.

RAYMOND E. FRANKS was born in Gainesville, Texas, on August 26, 1928. He received a BS degree in electrical engineering in 1950 from Rice Institute.

From 1950 to 1957, he was with the General Electric Co. Missiles and Ordnance Systems Division in Pittsfield, Mass., engaged in the design and evaluation of fire control and search radar systems. Mr. Franks joined the Sylvania Electronic Defense Laboratories, Mountain View, Cal. in May 1957, and since that time has been engaged in the development of broadband antenna systems for electronic countermeasures. He is a member of Tau Beta Pi.



C. W. GILLARD majored in physics at UCLA, graduating in 1951 with an AB degree. He then joined the General Electric Co., Richland, Washington, where he undertook nuclear studies and experimental research.

In 1955 he joined Sylvania's Electronic Defense Laboratories, Mountain View, California, and acquired an active interest in antennas. Currently he is head of the Electromagnetics and Antenna Systems Group at EDL and is engaged in broadband microwave antenna research and development.

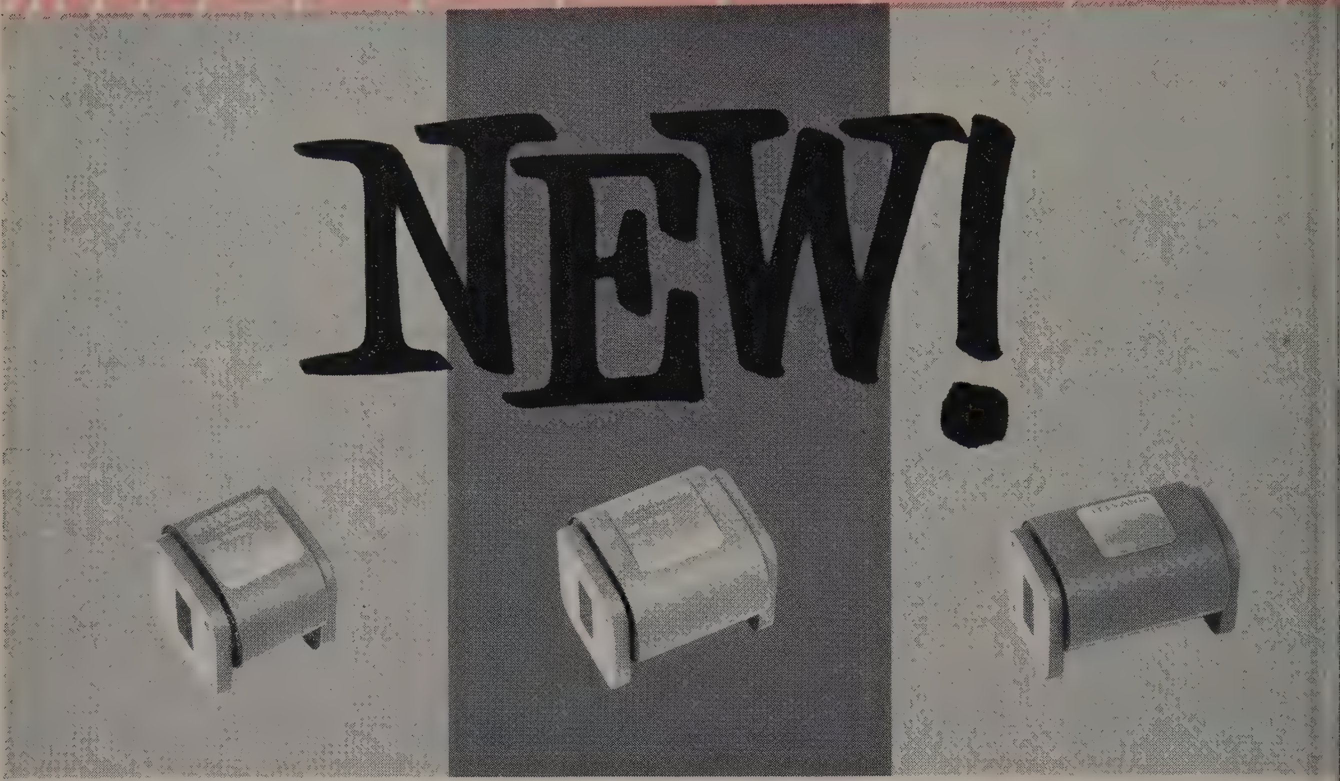
Mr. Gillard is a member of the American Physical Society, the IRE, PGMTT, PGAP, PGEM, and the American Mathematical Society.

JAMES K. PULFER was born in Gordon, Man., Canada, in 1932. He graduated from the Uni-versity of Manitoba with a BS degree in 1953.

He worked as a summer student with the Radio and Electrical Engineering Division of the National Research Council of Canada during 1952 and 1953. After a year of post graduate work at the University of Manitoba he returned to N.R.C. in 1954. He is presently engaged as an Associate Research Officer with the Radio and Electrical Engineering Division, where he is working on defense problems.

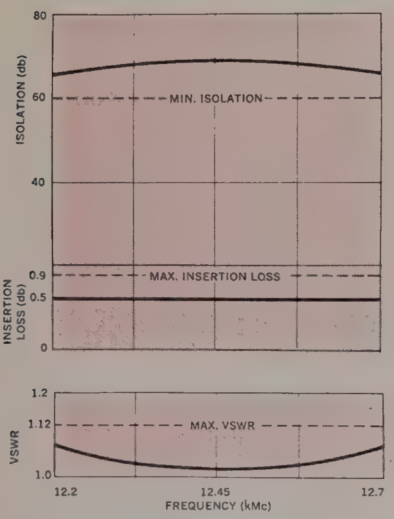
Mr. Pulfer is a member of the IRE and a member of the PGMTT.

MICROWAVE DEVICE NEWS from SYLVANIA



WR-75 waveguide ferrite isolators provide

FD-7516 — TYPICAL PERFORMANCE CHARACTERISTICS (25°C)



— high isolation — low insertion loss
— low VSWR — exceptional compactness

Sylvania introduces six new, narrow-band, high-performance ferrite isolators for cor mon carrier and commercial microwave systems. Sylvania FD-7511, -7512, -751 -7514, -7515, -7516 exhibit high isolation to insertion loss ratios, as much as 60 to over a broad frequency range. Lengths are from 2½″ to as short as 1½″. Sylvan WR-75 Ferrite Isolators exhibit unusually low VSWR and excellent stability over temperature range of −30°C to +60°C.

TYPE	FREQUENCY (KMC) Min.	FREQUENCY (KMC) Max.	MIN. ISO-LATION (db.)	MAX. INSERTION LOSS (db.)	VSWR (Input & Output)	LENGTH (Inches)
7511	10.7	11.7	20	0.4	1.2	1½
7512	10.7	11.7	40	0.7	1.2	2
7513	10.7	11.7	60	1.0	1.2	2½
7514	12.2	12.7	25	0.4	1.12	1½
7515	12.2	12.7	40	0.6	1.12	2
7516	12.2	12.7	60	0.9	1.12	2½

Investigate the advantages Sylvania's extensive ferrite devi line for your microwave desig Contact your nearest Sylvania Fie Office. Or, write Electronic Tub Division, Sylvania Electric Pro ucts Inc., Dept. MDO-B, 110 Main St., Buffalo 9, N. Y.

SYLVANIA

Subsidiary of **GENERAL TELEPHONE & ELECTRONICS**

AN ELECTRON DENSITY MEASURING SYSTEM FOR HOT PLASMA RESEARCH*

WILLIAM P. ERNST
PROJECT MATTERHORN
JAMES FORRESTAL RESEARCH CENTER
PRINCETON UNIVERSITY
Princeton • New Jersey

INTRODUCTION

Microwave diagnostic techniques have become valuable aids to the experimental physicist in the field of controlled fusion research. One of the important applications of microwave technology is in the determination of the electron density in a hot plasma where temperatures in excess of 10^6 degrees are attained. Knowing the time dependency of the electron density provides an insight to recombination, diffusion, degree of ionization, etc. In the stellarator and magnetic mirror machine** concepts of a controlled fusion device, the range of electron densities varies from 10^{13} to 10^{14} electrons per cubic centimeter. Because of the combination of large size and high density, the use of the more familiar resonant cavity techniques to determine electron density is impractical. A probe is not desirable because of the perturbation effects of the probe upon the plasma. However if an electromagnetic plane wave can be propagated through the plasma we may determine the average electron density by noting the effect of the plasma upon the microwave propagation properties. The physical dimensions of the plasma region and, as will be shown subsequently, the magnitude of the electron density dictate the use of millimeter microwave energy. Specifically, 8-mm and 4-mm wavelengths are ideally suited for the stated conditions.

The subject of microwave interaction with an ionized medium has been thoroughly treated elsewhere,[1,2,3] and the author does not presume to expand along those lines. The purpose of this paper is to describe in greater detail a measuring system*** which provides information about the time varying electron density in an ionized media.

GENERAL DESCRIPTION

The primary function of the electron density measuring system is to indicate the phaseshift of a microwave signal which is being beamed through an ionized medium. The reader who is acquainted with well-established methods for measuring phaseshift of microwaves may wonder about the significance of this particular system of measurement. Most schemes are suitable for measuring phaseshifts up to 2π radians and do not distinguish total phaseshifts more than 2π radians, and the measurement is generally done on a steady state basis. However, in the majority of plasma experimental devices, the phenomena being observed are of a transient nature. We are dealing with a phaseshift that varies with time, and furthermore, it is often much greater than 2π radians. The system under discussion is capable of measuring electron density under the latter conditions. In short, a swept millimeter klystron oscillator is used to power a highly dispersive microwave bridge circuit. The interference output of the bridge unbalance detector is applied to appropriate circuitry which will yield a striped, intensity-modulated oscilloscope display. Figure 1 is a picture of a typical 8-mm system.

PHASESHIFT vs. ELECTRON DENSITY: THEORY

It will be helpful at this point to review some of the highlights of the theory concerning the propagation of a plane electromagnetic wave through an ionized media. The previously mentioned references cover in greater detail the wave equations and propagation characteristics.

---

* *This work was supported under Contract AT(30-1)-1238 with the Atomic Energy Commission. Reproduction, translation, publication, use and disposal in whole or in part, by or for the United States Government is permitted.*

** *An excellent introduction to controlled fusion research is A. Bishop's "Project Sherwood," Addison-Wesley Publishing Company.*

*** *To the author's knowledge the type of measuring system described was first introduced by C. B. Wharton, Ref. 1.*

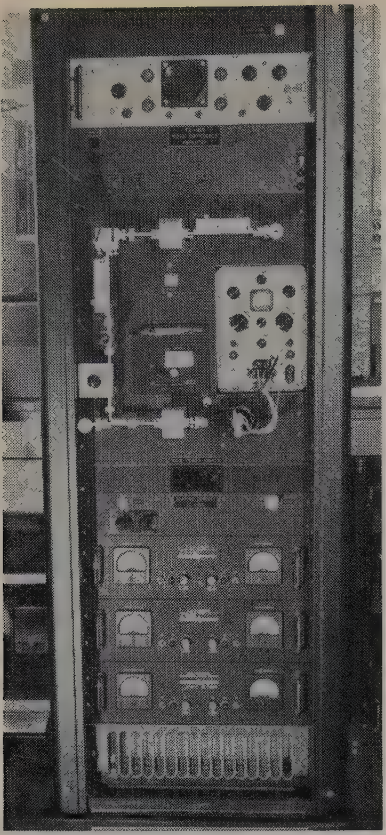


Figure 1 — Eight millimeter electron density measuring system.

Here, our specific goal will be to show that the electron density of a plasma may be calculated by measuring the phaseshift of a microwave signal being beamed through the plasma region.

There are four common and simple methods of propagation of electro-magnetic wave in a plasma immersed in a magnetic field.

a) Electric field parallel to the magnetic field ($E \| B_o$) with the propagation perpendicular to B_o.

b) Electric field perpendicular to the magnetic field ($E \perp B_o$), with the propagation perpendicular to B_o.

c) Right circularly polarized wave propagating in the direction of the magnetic field.

d) Left circularly polarized wave propagating in the direction of the magnetic field.

Type a) has the same propagation characteristics as the condition of zero magnetic field and is the mode used for the measurement technique under discussion. For the types b), c), and d) there are associated magnetic field dependent stop and pass bands, and these modes are sometimes used for other diagnostic measurements.

To summarize, the conditions that prevail in the stellarator and magnetic mirror experimental fusion machines are:

a) The electron-neutral particle collision frequency, ν_c, is very much less than the plasma radian frequency.

b) The diameter of the plasma sample is much greater than the free space wavelength of the microwave frequency.

$$\frac{D}{\lambda} \gtrsim 10$$

c) The electric field of the microwave plane wav is parallel to the magnetic field lines in th plasma region and is propagated perpendicula to the magnetic field.

$$E \| B_o$$

To simplify our equations it will also be assumed th there is a uniform (rectangular) distribution of electro density within the plasma. This is not always true, bu appreciable error will not be introduced by the assumption.

Under the above conditions it may be shown that th phase coefficient, β, of the uniform plane wave propagating through the plasma is

$$\beta = \frac{\omega}{c}\left[1 - \left(\frac{\omega_p}{\omega}\right)^2\right]^{1/2}$$

where

$\omega = 2\pi$ times the microwave frequency, f

c $\left\{ = \right.$ velocity of propagation of wave in fre space

$\left\{ = \right.$ 3 x 10^8 meters/sec

$\omega_p =$ plasma radian frequency

The plasma radian frequency is the frequency which electrons oscillate about their rest positions, and related to the electron density by

$$\omega_p^2 = \frac{n\,e^2}{m\,\epsilon_o}$$

where

e = electron charge = 1.6 x 10^{-19} coulomb

m = electron mass = 9.1 x 10^{-31} kg

ϵ_o = dielectric constant = $\frac{1}{36\pi}$ x 10^{-9} farads meter

n = electrons per cubic centimeter

The plane wave will propagate through a plasma whe $\frac{\omega_p}{\omega} < 1$ and will be cut off when $\frac{\omega_p}{\omega} > 1$. The poin corresponding to condition $\frac{\omega_p}{\omega} = 1$ is called the critic density n_c,

$$\omega^2 = \omega_p^2 = \frac{n_c\,e^2}{m\,\epsilon_o}$$

from which we solve for n_c

$$n_c = 1.24 \text{ x } 10^{-8}\, f^2 \text{ electrons/cm}^3.$$

The plasma frequency, f_p, may also be solved for in term of the electron density. Thus

$$f_p = 8974\sqrt{n} \quad . \quad \text{cps}$$

For an electron density of 1.5 x 10^{13} electrons/cm³, th plasma frequency would be 35 kMc. Frequencies belo this would not be propagated through the plasma, bu would be reflected in the same way as a waveguide beyon cutoff reflects energy.

Listed below is a table of critical electron densities *vs* plasma frequencies.

n_c electrons/cm³	f_p kMc
1.5×10^{13}	35
3.1×10^{13}	50
6.0×10^{13}	70
1.25×10^{14}	100
2.45×10^{14}	140

Since the electron densities of interest fall within range indicated in the table, the reason for using millimeter wavelengths for the phase measurement is evident.

The expression for the phase coefficient, β, may also be written in terms of the measured and critical electron densities.

$$\beta = \frac{\omega}{c}\left[1 - \frac{n}{n_c}\right]^{1/2} .$$

The phase coefficient through free space is given by

$$\beta_o = \frac{\omega}{c} .$$

Thus the phase change due to introducing plasma into the path length d, is

$$\begin{aligned}\Delta\phi &= \phi_o - \phi \\ &= \beta_o d - \beta d \\ &= \frac{\omega}{c}\, d\left[1 - \left(1 - \frac{n}{n_c}\right)^{1/2}\right] .\end{aligned}$$

The phase change will make itself evident as a fringe shift and will be equal to

$$\Delta\phi = 2\pi\ N \text{ radians}$$

where

N = the number of fringe shifts observed on the oscilloscope display. One fringe shift is defined as the condition of the top of one fringe extending to a line level with the top of the next fringe (360°). (The subject of fringe shift is treated in the next section)

Equating the two expressions for $\Delta\phi$ and solving for the electron density gives

$$n = n_c\left[\frac{2\,Nc}{fd} - \frac{N^2 c^2}{f^2 d^2}\right]$$

or

$$n = n_c\left[\frac{2\,N\lambda}{d} - \frac{N^2 \lambda^2}{d^2}\right]$$

where

$$\lambda = \frac{c}{f} .$$

The above expression may be normalized in terms of the plasma diameter and wavelengths by letting

$$\phi' = \frac{N\lambda}{d}$$

thus

$$\frac{n}{n_c} = 2\phi' - \phi'^2 .$$

A universal graph of $\frac{n}{n_c}$ or $\left(\frac{\omega_p}{\omega}\right)^2$ vs ϕ' is shown in Figure 2.

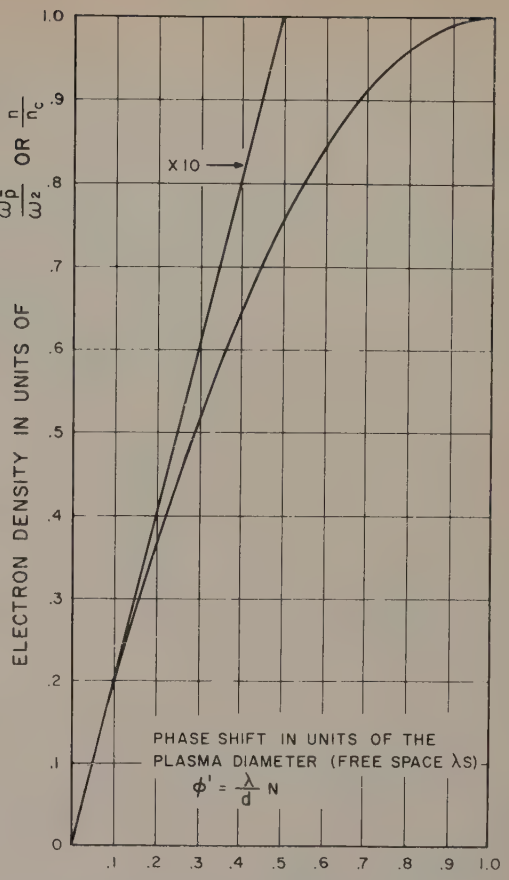


Figure 2 — Universal density — phase shift curve for parallel polarization ($E \| B_0$) and uniform density.

Example:

Plasma diameter = 2 1/2″ = 6.35 cm
Microwave frequency = 35 kMc
Free space wavelength = 0.857 cm
Number of fringe shifts observed = 2

Solution:

$$\phi' = \frac{(2)\ (0.857)}{6.35} = 0.270 .$$

From Figure (2)

$$\frac{n}{n_c} = \left(\frac{\omega_p}{\omega}\right)^2 = 0.470 .$$

at f = 35 kMc

$$\begin{aligned}n_c &= 1.242 \times 10^{-8}\ f^2 \\ &= 1.52 \times 10^{13} \text{ electrons/cm}^3\end{aligned}$$

therefore

$$n = 0.470\ n_c = 0.715 \times 10^{13} \text{ electrons/cm}^3$$

SYSTEM OPERATION

The operation of this phase display scheme requires a dispersive (i.e., frequency sensitive) bridge, obtained by making one arm very much longer than the other. Reference to the simplified system block diagram, Figure 3, will be made in the following paragraphs.

In order to provide "X" fringes (or stripes) on the oscilloscope raster, the differential pathlength ΔL required, in terms of free space wavelength, is

$$\frac{\Delta L}{\lambda} = X \cdot \frac{f}{\Delta f} \cdot \frac{\lambda}{\lambda g} \quad *$$

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* *See appendix*

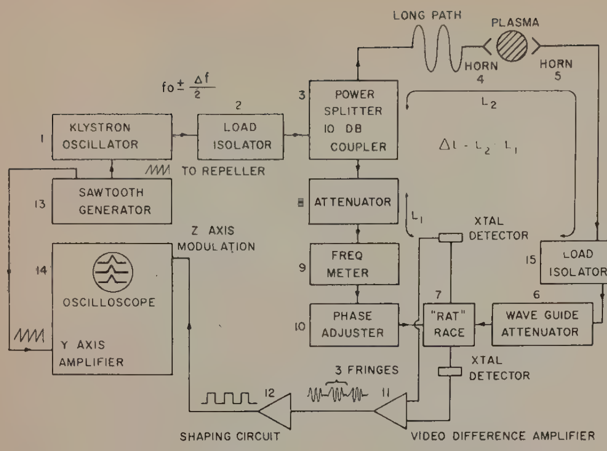

Figure 3 — Block diagram — electron density measuring system.

where

Δf = frequency modulation width
λg = guide wavelength
λ = free space wavelength
f = frequency of operation

The ratio of $\frac{\Delta f}{f}$ is limited by the klystron** oscillator characteristic in two ways. 1) The linear range of frequency vs. repeller voltage, and 2) the variation of RF output power vs. repeller voltage. In practice the latter is limited to a power variation of about 1.0 db. which generally satisfies the linear frequency change requirement. For instance, to obtain three stripes on the raster display $(X = 3)$ with an operating frequency of 35 kMc the $\frac{\Delta L}{\lambda}$ ratio may be calculated as below

$$f = 35 \text{ kMc}$$
$$\Delta f = 35 \text{ mc}$$
$$\frac{\lambda}{\lambda g} = .798$$
$$X = 3$$

from which

$$\frac{\Delta L}{\lambda} = \frac{(3)\ (35 \times 10^9)\ (.798)}{35 \times 10^6} = 2400 \ .$$

Since

$$\lambda = .856 \text{ cm}$$
$$\Delta L = (2400)\ (.856) = 2060 \text{ cm} = 60 \text{ ft.}$$

To generate the frequency-modulated signal a sawtooth generator (13) applies a high-level (up to 45 v peak to peak) voltage through a high-voltage coupling capacitor to the repeller lead of the klystron. The klystron output is fed through a load isolator (2) to a power splitter (3). This unit is a 10 db. directional coupler with 90 per cent of the input power going to the long leg and 10 per cent to the short leg. The higher signal level is then transmitted via waveguide to the transmitting horn (4), through the plasma enclosure and received by a similar waveguide horn (5). (Under normal operation the polarization of the electric field as radiated is parallel to the magnetic field within the machine.) From the receiving horn the signal is sent to the balanced detector (7) through a waveguide attenuator (6). The lower level output of the power splitter (3) is fed through a waveguide attenuator (8), which is used to adjust the relative levels of the two signals at the balanced detector. The phase adjustor (10) may be used to check system operation and also to center the display on the oscilloscope (14). There is incident on the balanced detector two signals, and if the klystron frequency were constant the output of the balanced detector could be nulled by making the attenuation and phaseshift equal in each leg. However, when the klystron frequency is changed, the phase of the long leg signal varies more rapidly than the phase of the signal in the short leg, due to the dispersive action of the differential pathlength. If the differential pathlength is great enough there will result a sine wave output from the balanced detector corresponding to the in and out of phase relationship of the two incident signals to the balanced detector. As indicated on the block diagram, there are 3 fringes at the video difference amplifier. For a given installation the number of fringes is controlled by the klystron sweep width, Δf. The phase relationships of the two crystal outputs and the individual gain adjustments of the video difference amplifier will provide a nearly amplitude modulation free output. The output of the video difference amplifier is applied to the shaping circuit where it is amplified and clipped so that essentially a square waveform results with sufficient amplitude to intensity-modulate the oscilloscope. The same sawtooth generator that modulates the klystron repeller also supplies a lower, fixed amplitude sawtooth waveform to the vertical amplifier of the oscilloscope. Depending upon the relative settings of the oscilloscope sweep speed and the sawtooth frequency a "striped" raster will be present when the shaper amplifier output is applied to the oscilloscope intensity-modulation input. Figure 4 shows typical waveforms obtained at various system check points.

The above description of the system operation covers the static conditions, i.e., no plasma between the transmitting and receiving horns. However, when a plasma is introduced into the transmission medium, the dielectric constant of that medium is changed. The changing di

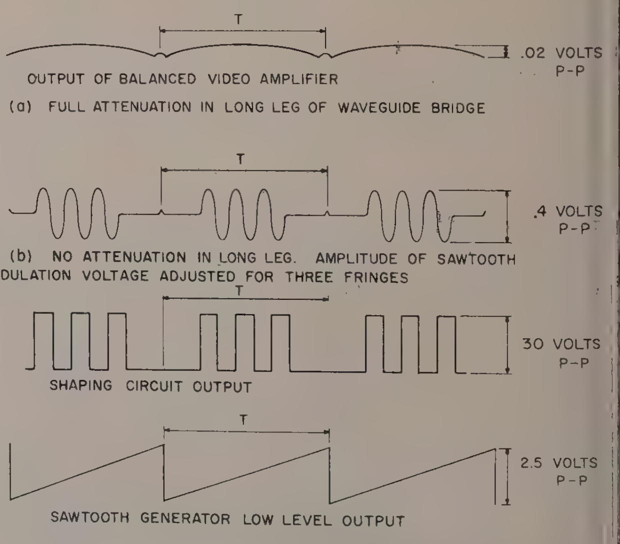

Figure 4 — System Waveforms.

*** The use of backward-wave oscillators would provide a higher Δf/f ratio and would enable the use of a smaller differential path length. Since klystrons are readily available at the frequencies of interest and also more economical, they have been used in the present systems.*

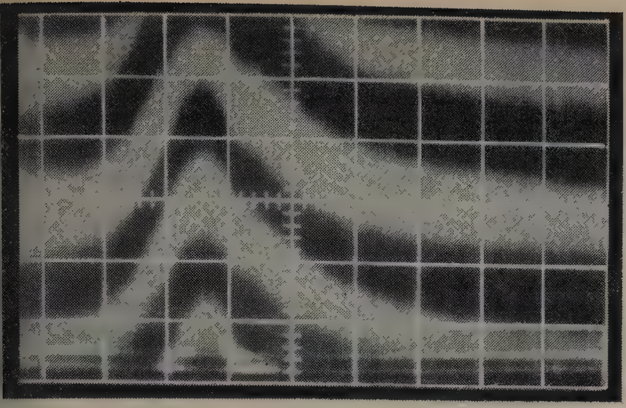

Figure 5 — Typical oscilloscope "striped" display time base — 500 microsec/cm. Band shift, N = 1.

electric constant will change the wavelength of the microwave energy through the medium, and in turn the phase of the microwave signal at the receiving horn will vary. This phase variation will be indicated by a shift in phase (relative to the sawtooth sweep voltage) of the fringes or stripes on the oscilloscope display. A shift of one stripe spacing represents 360° or 2π radians phase change. Figure 5 illustrates the typical oscilloscope display. It has been shown previously that the total phase-shift is related to the electron density of the plasma depending upon frequency of operation, plasma diameter, and electron density distribution.

CIRCUIT DESCRIPTION

1. Sawtooth Generator.

The sawtooth generator must supply a high-level sawtooth voltage for modulating the klystron and also a low-level duplicate at the modulating voltage to be applied to the "Y" axis amplifier of the oscilloscope. The sawtooth frequency may be varied between 100 kc and 1 megacycle, the highest frequency providing good resolution with oscilloscope sweep times as fast as 50 microseconds per cm. It should be noted that any difference in wave shape between the high-level and low-level voltages will cause nonlinearities in the visual display. Because of the high impedance of the modulation circuit it has been found necessary to keep the coaxial cable length between the sawtooth generator and the klystron repeller connection as short as possible in order to avoid capacitive loading effects. The low-level output has a source impedance of 75 ohms which permits a long run of coaxial cable to the oscilloscope, without distorting the sawtooth wave shape.

2. Waveguide Bridge Circuit.

The bulk of the waveguide components in the bridge network is part of the waveguide panel on the test set. The long leg of the bridge is formed by the waveguide run to and from the plasma source. In the 8-mm and 4-mm systems it has been found satisfactory to use RG-96/u waveguide for the long straight sections without experiencing excessive attenuation. In the 4-mm system it is advisable to taper down to RG-98/u waveguide before going through bends, twists, etc. The eventual use of 2-mm waves (which will be required with electron densities in excess of 10^{14} electrons/cm^3) may require the use of circular waveguide operation in a low-loss mode or some form of dielectric waveguide.

3. Video Difference Amplifier.

The output of the balanced mixer is essentially an amplitude modulated (AM) carrier waveform. The AM is due to the output power variation of the klystron as its frequency is being changed, and the carrier waveform is generated by the dispersive action of the microwave bridge network. The video difference amplifier does a twofold job. First, since the AM outputs of the crystals are in phase, the difference action, after proper adjustment of the individual amplifier channels, will cancel the AM. However, the "fringe" or carrier waveform output of each crystal is 180° out of phase and therefore will add in the difference amplifier. The overall maximum gain of the amplifier is approximately 40 db with a 15-megacycle bandwidth. It has been found advantageous to include individual forward biasing for each video detecting crystal (0.1 to 0.5 volts) which results in an average of 10 db increase in crystal sensitivity. Other features within the amplifier include individual channel gain adjustment, overall gain control and a high-frequency balance control. All filaments are powered by a dc source for minimum ripple.

4. Shaping Circuit.

The primary function of the shaping circuit is to amplify and clip the "fringe" waveform output of the video difference amplifier. The square wave output of 30 volts peak to peak and with a rise time of about 0.1 microsecond is of sufficient amplitude to intensity-modulate the viewing oscilloscope. Normal output may be obtained with a 10-millivolt peak-to-peak input signal. Since the output level of the difference amplifier is adjusted to 500 millivolt peak-to-peak; a wide range of limiting is provided and allows for appreciable variation in the microwave signal level. Precaution must be taken when transmitting the square waves over a long distance by way of coaxial cable. Any impedance mis-match will alter the original waveform and thus produce distortion on the visual display. A wide-band video line transformer or a line amplifier may be used to terminate the long line and still provide the required peak-to-peak voltage necessary for the intensity modulation.

5. Vacuum Techniques.

In most controlled fusion experimental devices the plasma is generated in an ultrahigh vacuum region where vacuums in the order of 10^{-10} to 10^{-11} mm of mercury are maintained. To achieve the desired vacuum, among other steps, the system must be baked out at temperatures of 500°C. Thus to transmit the microwaves through the plasma region a waveguide window must be capable of holding a high vacuum, and withstanding high bakeout temperatures. The most satisfactory solution[4] thus far has been to use a Kovar cup which has a glass window sealed on one end. The cup is then fusion-welded to the flange of the access port. Figure 6 shows a cross-section of a typical waveguide flange assembly.

CONCLUSIONS

The system that has been described can be adapted to any microwave frequency range with just a change in the waveguide bridge components. The significant features of the measuring scheme are:

a) The deflection of the oscilloscope pattern is directly proportional to phaseshift, which in turn is nearly proportional to electron density when the electron density is low ($n/nc \lesssim 0.5$).

b) Direct and continuous calibration in terms of interstripe spacing.

c) Wide dynamic range of phaseshift, because as one stripe leaves the scope face another replaces it.

d) Discrimination against amplitude changes in the microwave signal, by means of limiting action in low-frequency electronic circuits.

The limitations of the systems are:

a) Insensitive to small phaseshifts ($\triangle\phi << \pi/2$).

b) Poor stability for measurements of a steady-state phase change.

c) The use of a sweep frequency which may limit time resolution.

Although the density-measuring system has been tailored for use on a particular type of plasma research device, it is felt that some of the techniques involved may be of interest in other fields of plasma physics. For instance, if the propagating frequency is below the plasma frequency there will be almost complete reflection of the microwave signal for $E \| B_o$. By sampling the reflecte signal and noting its phase change, an indication c plasma motion may be observed.

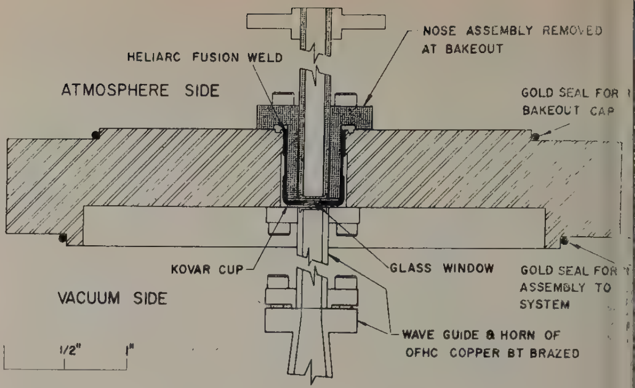

Figure 6 — Microwave window assembly.

ACKNOWLEDGMENT

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APPENDIX

Frequency sensitivity of bridge network.

Referring to Figure 3, the difference of phase at the balanced detector (7) is

$$\triangle\phi = \frac{2\pi(L_2 - L_1)}{\lambda g} = \frac{2\pi \triangle L}{\lambda g} \quad . \qquad (1)$$

To find $\frac{d(\triangle\phi)}{df}$ we must first find λg as a function of frequency. For rectangular waveguide operating in the dominating mode, λg is given by

$$\lambda g = \frac{\lambda}{\left[1 - \left(\frac{\lambda}{2a}\right)^2\right]^{1/2}}$$

where

$\lambda =$ free space wavelength

$a =$ waveguide width

since

$$\lambda = \frac{c}{f}$$

$$\lambda g = \frac{c/f}{\left[1 - \left(\frac{c}{2af}\right)^2\right]^{1/2}}$$

rearranging

$$\lambda g = \frac{2\,ac}{\left[4a^2f^2 - c^2\right]^{1/2}} \qquad (2$$

substicuting into Equation (1)

$$\triangle\phi = \frac{2\pi \triangle L}{2\,ac} \cdot \left[4a^2 f^2 - c^2\right]^{1/2}$$

and

$$\frac{d(\triangle\phi)}{df} = \frac{1}{2} \frac{\pi \triangle L}{ac} \cdot \frac{1}{[4a^2f^2 - c^2]^{1/2}} \cdot 8a^2f$$

multiplying by $\frac{c}{c}$, substituting Equation (2) and rea ranging,

$$\frac{d(\triangle\phi)}{df} = \frac{2\pi \triangle L}{\lambda^2 f} \cdot \lambda g = \frac{2\pi \triangle L}{\lambda} \cdot \frac{\lambda g}{\lambda} \cdot \frac{1}{f}$$

The total number X of fringes produced at th balanced detector output for a frequency increment $\triangle f$,

$$X = \frac{\triangle(\triangle\phi)}{2\pi} = \frac{\triangle L}{\lambda} \cdot \frac{\triangle f}{f} \cdot \frac{\lambda g}{\lambda} \quad .$$

Design of
LOW NOISE GUNS FOR TRAVELING WAVE TUBES

F. B. FANK
POWER TUBE DEPARTMENT
GENERAL ELECTRIC COMPANY
Palo Alto • California

I. INTRODUCTION

The design of a low noise traveling-wave tube is complicated by the many variables which affect its performance. The general procedure for the design of a low noise tube consists of computing a rough design from basic noise theory coupled with an empirical determination of any improvements. Another very successful way to approach an approximate design is through the use of the frequency scaling laws[1] with an already known design as a basis. It is the purpose of this paper to make available sufficient information with a straightforward design procedure so that the first design of a low noise tube can be made simply, with a minimum of subsequent empirical work. Several excellent papers on this general subject have been published in the past;[2,3] it is hoped that this paper will bring the subject matter up to date as well as present a simpler design method.

The basic low noise design outlined in this paper has been applied to traveling-wave tubes at the General Electric Microwave Laboratory and in similar form to many tubes at other laboratories. The optimum noise figures achieved by the use of these methods range from 4.5 db at 3.0 kmc,[4] to 6.2 db at 9.0 kmc,[5] to 11.5 db at 40.0 kmc.[6]

Considerable improvement in the noise figures of traveling-wave tubes has been achieved recently by paying particular attention to the voltage profile in the proximity of the cathode surface.[7] These new techniques will be treated in this paper as a refinement to the basic low noise gun design since the exact details and the theory are not yet well established. These methods, which were first discovered in backward wave amplifiers, are now being applied to forward wave tubes as well.[8] Traveling-wave tubes which use these designs have measured noise figures of 2.7 db at 3.0 kmc[9] and 4.5 db at 9.0 kmc.[10]

The basic low noise design applies equally well to forward wave and backward wave amplifiers. The details for designing a backward wave tube are slightly different because a hollow beam is normally used instead of a solid beam and the slow wave circuit loss has more effect on the noise figure.[11]

II. GENERAL OUTLINE OF LOW NOISE TUBE DESIGN

Gain in a traveling-wave tube is the result of the interaction between a moving electron beam and the electric fields traveling on a slow wave circuit which is electromagnetically coupled to the beam. Since all of the tube noise originates in the electron beam, it is the r-f behavior of the beam with which we are most concerned in designing a low noise tube. The r-f behavior of the beam is normally described in terms of plasma or space charge waves. Any perturbation of the beam by an impressed current or velocity modulation sets up a local plasma oscillation which, when viewed on the moving electron stream, appears to propagate down the beam. The plasma oscillation determines the amplitude modulation of the radio frequency space charge waves on the beam in a way similar to that in which an audio signal amplitude modulates an r-f carrier. The similarity of the equations for the propagation of these plasma waves with the wave equations for a uniform transmission line allow many of the standard concepts of transmission line theory to be used in describing the behavior of plasma waves on an electron stream.[12] Thus, the electron beam can be considered to have a characteristic impedance and the waves traveling on it will set up standing wave patterns.

The fundamental noise modulation in the beam originates at the cathode and can be described in terms of two uncorrelated sources: velocity fluctuation noise and current or shot noise.[13] The noise modulation is due to the fact that the electrons which come from the cathode have random thermal velocity fluctuations and are emitted in a random time sequence. The velocity fluctuations, which follow a Maxwellian distribution, constitute one independent noise source, and the randomly emitted electrons create the independent current noise source commonly called "shot noise." At the potential minimum, it is generally assumed that these two noise sources are uncorrelated.[13] Thus, the two noise sources independently set up noise signals which propagate along the electron beam from the potential minimum to the input of the slow wave interaction circuit, which is a helix in most low noise tubes. What happens to these two noise waves as they propagate down the electron stream and how to modify them for low noise operation is the subject of low noise gun design.

Considered separately, each source produces a wave with an infinite standing wave ratio, but together the two signals form a finite voltage or current standing wave ratio whose magnitude is a function of the cathode starting conditions and of the beam parameters at any given point. It has been shown theoretically[14] that the optimum noise figure occurs when the resultant standing wave ratio in the beam at the input of the slow wave circuit has a definite magnitude and phase which is a function of the beam-circuit parameters: Q, C, and d. The general problem, then, is the proper transformation of the current standing wave ratio at the potential minimum to that required at the input of the slow wave circuit; this is accomplished by a method similar to the variation of the characteristic impedance of a transmission line. It will be assumed here that the circuit design has already been established by the requirements of gain and bandwidth, so that the required standing wave ratio (beam impedance level) and phase at the input of the circuit are already known.

The region between the cathode potential minimum and the circuit input is the noise transducer section which may be divided into three distinct parts. The first is the space charge limited diode section between the cathode and current control anode; the second is the impedance transformation section between the anode and the drift tube; the third is the drift tube section, a region of constant beam impedance which is usually necessary because of practical gun construction requirements. An outline of a low noise electron gun with a typical voltage profile is shown in Figure 1.

The voltage profile in the electron gun region transforms the space charge standing waves in order to "match" the required amplitude and phase into the slow wave circuit, and it is the shaping of this profile which constitutes a major part of the low noise gun design. In reality, there is considerable flexibility in this design because voltages can be adjusted over a wide range to obtain the proper profile for many different electrode spacings.

A simple physical picture of what is happening to the noise modulation in the beam helps in understanding the design of the gun. In this case, the transmission line analogy makes it particularly easy to describe the operation of the low noise gun. At the potential minimum plane, the two noise sources combine in a space charge standing wave whose voltage ratio is close to one in an optimally designed gun.[2] As these waves pass through the diode region to the control anode, the standing wave ratio becomes large due to the change of beam impedance in this region required by the Child-Langmuir space charge law. At the control anode plane, the standing wave ratio can range from ten to fifty, depending upon the frequency of operation and tube design. Therefore in the exponential impedance transformation region, the voltage profile must be of the proper shape; that is, the beam characteristic impedance must vary in the proper way to bring this standing wave ratio down to the value determined by the circuit parameters; this value typically ranges from 1.5 to 4.0. In the drift or constant voltage region, the standing wave ratio maintains a constant magnitude but advances its phase until, at the circuit input the correct standing wave magnitude and phase are obtained for minimum noise figure.

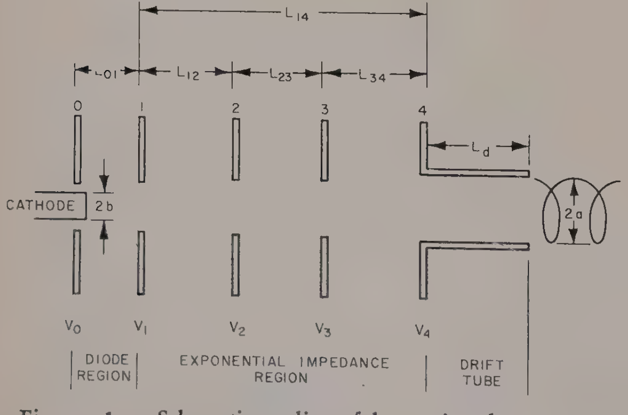


Figure 1 — Schematic outline of low noise electron gun.

III. DESIGN FOR OPTIMUM NOISE FIGURE

In this section, the detailed design of the electron gun shown in Figure 1 will be considered. The parameters which must be determined in the design of a low noise gun are the following: (A) current density, (B) anode spacings (L_{01}, L_{12}, L_{34}) and voltages, (C) anode aperture diameters, and (D) length of drift tube, L_d. The design of the helix or other slow wave circuit is determined by gain, frequency, and bandwidth requirements and is discussed elsewhere.[15]

Current Density

The required beam current is normally obtained from the gain requirement of the tube. With the current known, the current density, and therefore the diameter of the beam, can be found from Equation 1, below, which gives the normalized wave impedance at the potential minimum plane in terms of the current density, frequency, and cathode temperature. Optimum design of the nose reduction section of the gun requires the normalized impedance, r_1, to be as close to one as is practically possible.[2]

$$r_1 = 1.52 \times 10^{-9} f \frac{T_c^{1/4}}{J_{01}^{1/2}} \qquad (1)$$

where

r_1 = normalized wave impedance at potential minimum,
f = frequency in cycles per second,
T_c = cathode temperature in degrees Kelvin,
J_{01} = beam current density in amperes per square meter.

This condition cannot always be met because of the limitations on available current densities consistent with long life. It will be shown in Section IV, where the actual designs of several tubes are given, that for the very high frequency tubes, a normalized impedance approaching one cannot be practically obtained. In these cases, the highest practical current density is used to obtain as low an r_1 as is possible.

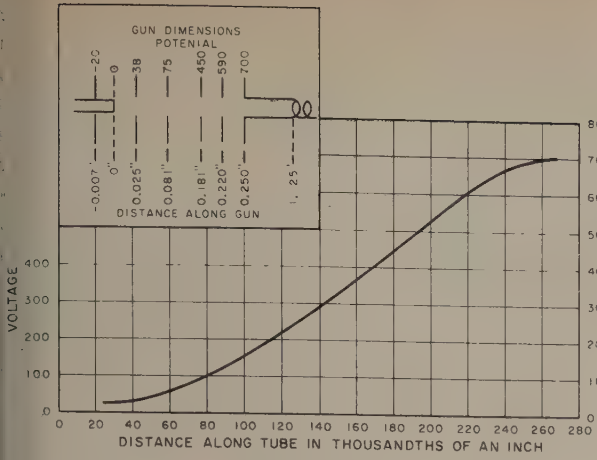


Figure 2 — Voltage profile, X-band tube.

Anode Spacings and Voltages

The next step is to determine the anode voltage and the anode-to-cathode separation. These parameters are related by the Child-Langmuir law, Equation 2.

$$J_{01} = \frac{2.335 \times 10^{-6} V_1^{\ 3/2}}{L_{01}^{\ 2}} \quad \text{amperes per unit area,} \qquad (2)$$

where

V_1 = anode-cathode potential, volts.

For optimum performance, the anode voltage should be as low as possible to (1) reduce the standing wave ratio at the anode plane because the ratio is directly proportional to the anode voltage,[2] and (2) to allow a large voltage change between the anode and the circuit. Since the anode voltage, for a given current density, becomes smaller the closer the anode is to the cathode, it is desirable to decrease L_{01} to a minimum. For normal parallel flow electron guns, the cathode-to-anode spacing should not be less than the cathode diameter itself to minimize transverse electric fields, and a safe value is twice the cathode diameter. Setting a value for L_{01} gives V_1 from Equation 2. Knechtli and Beam[2] point out that a quasi-divergent beam in the cathode-anode region results in better noise conditions at the first anode plane. This condition is also determined empirically by alternate adjustment of the voltages on electrodes (0) and (1) to give minimum noise figure. As will be discussed in the Section V on refinements, the cathode-anode region is the one which is modified for obtaining ultra-low noise figures.

In the region where the impedance varies exponentially with distance, the voltage is almost a linear function of distance.[2] Examples of voltage profiles used in G.E. Microwave Laboratory tubes are given in Figures 2 and 4.

In the exponential gun region, several electrodes can be placed approximately uniformly along the gun region to adjust the voltage profile for an optimum noise figure. It has been found that two independent electrodes between the first anode and the drift tube give sufficient flexibility in the operation of the tube to achieve nearly optimum results. The voltages on the electrodes will correspond quite closely to those for an exponential impedance change. The actual voltages on electrodes (2) and (3) can be initially set up to give a linear voltage profile. The final values would then be determined empirically. As mentioned previously, the actual electrode spacings are not too critical because the voltages can be adjusted to give the proper profile. For flexibility and construction ease, a spacing arrangement where L_{23} is approximately two-thirds L_{34} has been found to be satisfactory. The position of the focusing electrode [electrode (0)] is made to give some flexibility in the beam conditions at the cathode plane by varying the potential on the electrode negative with respect to the cathode.[2] This is accomplished by placing the focusing electrode approximately one cathode radius behind the cathode face.

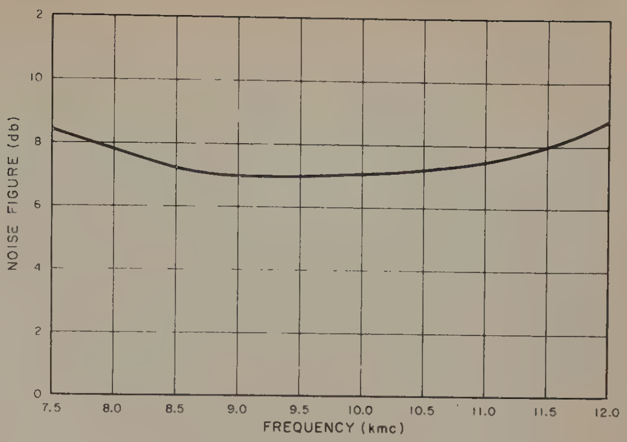


Figure 3 — Noise figure versus frequency, X-band tube.

Anode Aperture Diameters

The aperture diameters on all of the electrodes except the focusing electrode [electrode (0)] should be two or three times the cathode diameter to minimize electrostatic lens effects and mechanical irregularities. Too large an aperture diameter results in the fields from the surrounding electrodes penetrating through the aperture. This condition makes empirical optimization of the noise figure more difficult.

The next important dimension to be determined is the total length of the exponential gun region, L_{14}. Actually, several straightforward methods are available for determining this length with reasonable accuracy. One method which determines both the exponential gun region and drift tube length is the original velocity jump principle

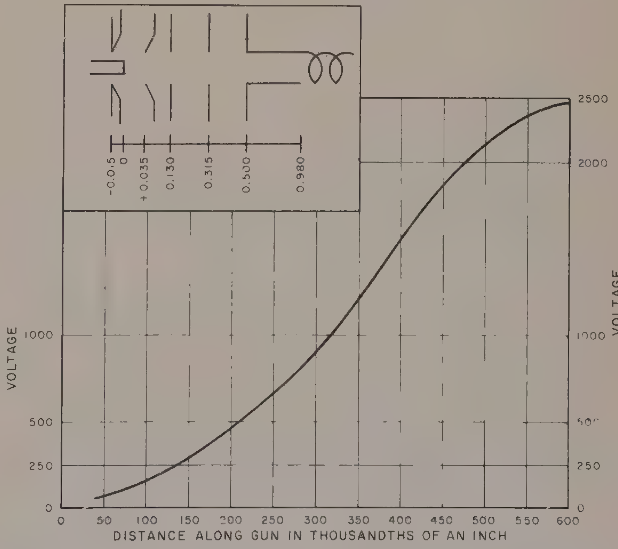


Figure 4 — Gun outline and voltage profile, K_u — band tube.

developed by Wakins.[16] The resultant design using this method has two constant voltage regions beyond the first anode with a discontinuous voltage step between them. In the physical design, this overall length is practically divided into a tapered voltage region and a constant voltage drift region. However, a simpler and more realistic method has been worked out by Knechtli and Beam[2] based on an actual exponential impedance variation. On the basis of theory and experience, they have found that a beam whose impedance varies between anode one and the drift tube in a manner given by Equation 3 will transform the standing wave ratio to its required value in an optimum manner.

$$\text{impedance} \sim e^{k\beta}, \qquad (3)$$

where k = constant $\cong$ approximately one,
β = plasma wave propagation constant.

Optimum in this case means best broadband frequency operation, minimum electrostatic lens effects, and least sensitivity to beam current changes. The gun length, L_{14}, then can be found from the following relationship:[2]

$$L_{14} = \frac{\ln \frac{p_4}{p_1}\left(\frac{V_4}{V_1}\right)^{3/4}}{k\beta\ \text{avg.}}, \qquad (4)$$

where

p = plasma frequency reduction factor[17]
V_1, V_4 = voltage at anode (1), (4)
β avg. = average plasma wave propagation constant between planes (1)and (4).

Drift Tube Region

The next region of interest is the constant voltage drift tube region in which the standing wave does not change in magnitude, but its phase is changed. The length of the drift region is then dictated, in principle, by the minimum noise figure phase requirement at the circuit input. However, it has been shown experimentally as well as theoretically that small changes in the voltage of electrodes (1) and (2) will considerably change the phase in the drift region.[2] Therefore, the drift tube length is not so critically determined by the phase requirement as it is by other considerations. The main consideration is that of frequency insensitivity. The plasma wavelength in a finite beam is a function of the r-f frequency and beam voltage, and its sensitivity to frequency increases with increasing beam voltage. Thus, in the drift tube region which is operated at the highest voltage, the wavelength of the noise standing waves changes most with operating frequency. Consequently, for best broadband operation, a short drift tube is desirable. On the other hand, if no drift tube is used, the required voltage change between anode (1) and helix is larger than if a finite drift length is used. Thus, if the helix voltage which determines V_4 is held as low as practical, V_1 also must be very low. Since V_1 is dictated by the requirement given previously, there is a limitation to this voltage change. In practice, the minimum drift tube length is usually determined by the mechanical design of the complete traveling-wave tube. Starting with this minimum length, the optimum length for the desired noise figure and bandwidth requirements can be obtained by building several tubes with successively longer drift tubes. A practical increment of length to add each time is the length require for a ninety degree phase change at the helix voltage.

Tube Construction Factors

While this paper is primarily concerned with the design of the electron gun, there are several other factors in the over-all design of the traveling-wave tube which have a significant influence on the noise figure and are worth mentioning briefly. These factors are interception noise secondary electron noise, and cathode construction. These will be discussed in turn.

Additional noise fluctuations are added to the beam when current is intercepted in either the gun or helix regions. However, the farther away from the input th interception occurs, the less effect it has on the nois figure. Proper internal alignment and focusing of th tube will greatly reduce this noise term. Secondary electron noise is due to secondary emission electrons emanating from the collector and amplifying noise in the backward direction.ˋ This backward noise wave can be made to travel in the forward direction and add to the normal forward wave by reflections and imperfect terminations By using collector materials which have a low secondary emission coefficient and by "spoiling" or deflecting the magnetic field in the collector region to deflect backward moving electrons, it is possible to make this effect negligible.

By far the most important strictly constructional component in the tube is the cathode. Since its emission characteristics affect the fundamental noise quantities, it is necessary to take every care in fabricating it. Very simply, the cathode should be designed to operate in a space charge limited condition at the lowest possible temperature, and the emissive coating should be uniform and dense over the entire emitting surface. Super-clean techniques are standard requirements for obtaining consistently good cathode characteristics.

IV. EXAMPLES OF LOW NOISE GUN DESIGN

In this section, two examples of successful low noise guns are presented. The first one is for an X-band tube which operates over the 7.5 kmc to 12.0 kmc range. The important tube parameters, gun voltage profile, and noise

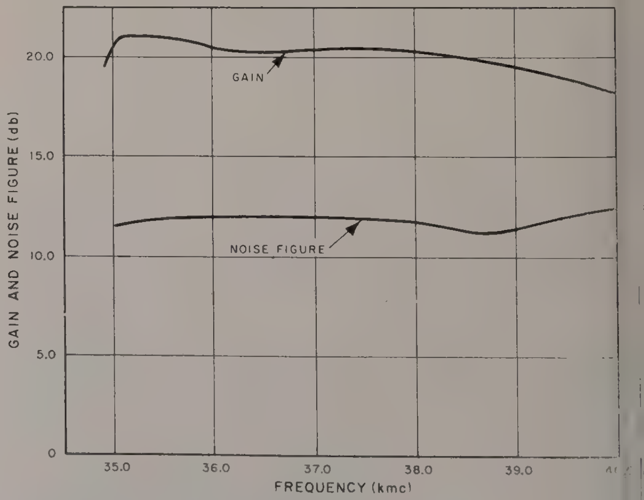
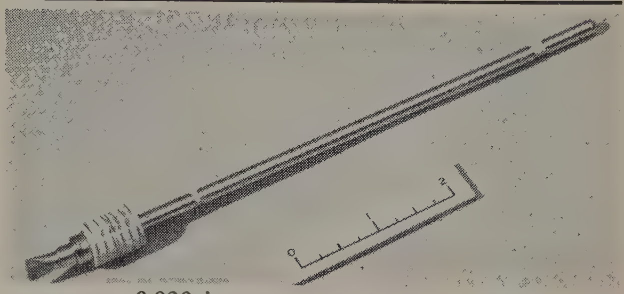


Figure 5 — Gain and noise figure versus frequency, K_a — band tube.

TABLE I

X-BAND LOW NOISE AMPLIFIER



Beam Current ≡ $I_o = 600\ \mu a$

Helix Voltage ≡ $V_o = 700$ volts

Gain Parameter[15] ≡ $C = 0.02$ (9.4 kmc)

Attenuation Parameter ≡ $d = 0.25$ (9.4 kmc)

Helix Radial Propagation (constant) x (helix radius) ≡ $\gamma a = 1.95$ (9.4 kmc)

Cathode Diameter = 0.020 in.

Helix ID = 0.036 in.

Helix OD = 0.044 in.

Normalized Impedance At Potential Minimum (9.0 kmc) $r = 1.28$

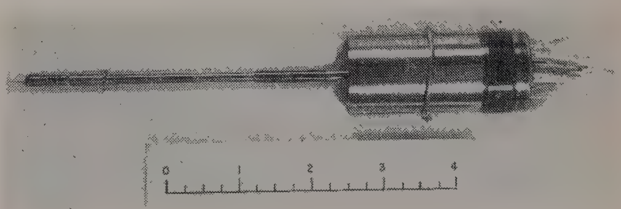
figure data are presented in Table I and Figures 2 and 3. A smaller cathode would improve the design slightly by bringing the normalized impedance, r, closer to unity, but it would also increase the cathode loading, which was not desirable in this case. The data shown is typical of production type metal and ceramic tubes. Experimental tubes have achieved lower noise figures in this frequency range. The second example is of a much higher frequency tube where the cathode loading problems are extreme. The frequency of operation is 35.0 kmc to 40.0 kmc, requiring cathode dimensions which were completely impractical. Consequently the tube could not be designed for the theoretical minimum noise figure, as can be seen by the value of normalized impedance at the potential minimum. A much larger helix voltage would be necessary to obtain a near minimum noise figure. Also, at these frequencies, the cold circuit loss becomes a very important factor because the noise figure increases with increasing circuit loss. The circuit loss is reflected in the factor, d, which for this tube is nominally 0.4 compared with a value of 0.25 for the X-band tube. Design data and performance curves are shown in Table II and Figures 4 and 5. Both of these tubes are examples of what can be achieved by following the low noise gun design discussed in this paper.

V. LOW NOISE REFINEMENTS

The design procedures outlined above will result in minimum noise figures starting around 6.0 db, the exact value depending upon the frequency of operation. These noise figures are determined by the magnitudes of the two noise sources at the potential minimum. It has recently been discovered that much lower noise figures can be obtained by appropriately modifying the potential profile in the vicinity of the potential minimum.[7] The modi-

TABLE II

K_a-BAND LOW NOISE AMPLIFIER



Beam Current ≡ $I_o = 500\ \mu a$

Helix Voltage ≡ $V_o = 2350$ volts

Gain Parameter[15] ≡ $C = 0.009$

Attenuation Parameter ≡ $d = 0.4$ (37.5 kmc)

Helix Radial Propagation (constant) x (helix radius) ≡ $\gamma a = 2.6$ (37.5 kmc)

Cathode Diameter = 0.013 in.

Helix ID = 0.021 in.

Helix OD = 0.029 in.

Normalized Impedance At Potential Minimum (37.5 kmc) $r = 4.06$

fied profile can do two things to the noise quantities: (1) it can allow the electrons to drift over an appreciable distance at a velocity comparable to the average noise velocity fluctuations (approximately 1.0 volt), and (2) it can distort the geometry of the beam emission to affect the velocity distribution in the beam. It is also possible that the beam shaping enhances space charge smoothing of the current fluctuations but, at the present time, this is not considered as probable as the change in velocity distribution. Both of these actions can reduce the minimum obtainable noise figure. In the first case, a drifting multi-velocity beam has been shown to increase the correlation between the two noise sources.[10] Since the minimum noise figure is directly dependent upon the correlation between the current and velocity fluctuations,[13] this effect has a reducing influence on the minimum noise figure. In the second case, the velocity distribution can be so altered as to reduce the magnitude of the noise velocity fluctuations. To do this, the higher velocity classes are cut off or reduced in number to weight the velocity distribution toward the lower velocity end. Recent experimental evidence[18] indicates that the dominant factor in the noise reduction is a change in the magnitudes of the noise sources rather than an increase in the correlation between the sources. To achieve these effects Currie and Forster[7] have shown that it is necessary to change the potential profile off the cathode from a normal Fry-Langmuir curve to a more axially depressed curve by having a divergent transverse electric field in this region. The transverse field is a necessary condition for reducing the axial potential to the low values required for a multi-velocity drift region to exist. One method for designing these low velocity drift regions into the standard low noise gun has been by placing several closely spaced electrodes near the cathode in addition to the regular electrodes.[11] The voltages for these electrodes are then biased to produce the two-dimensional electric field pattern. This condition usually requires the electrodes nearest the cathode to be positive with respect to the cathode. Another method for accomplishing similar results is to shape the cathode face, such as beveling the edges. Since there are quite a variety of cathode configurations and voltage profiles, these refinement techniques have not necessarily reached the ultimate in minimum noise figure.

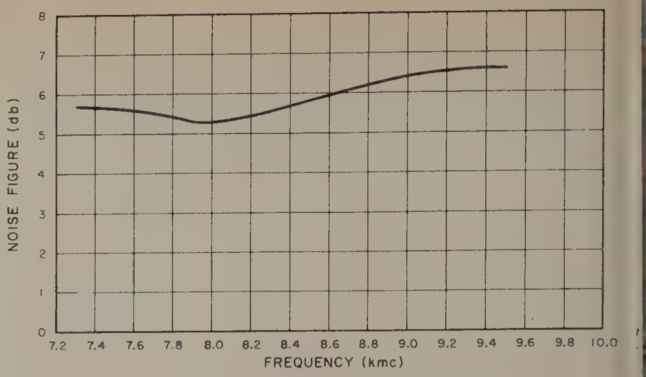


Figure 6 — Noise figure versus frequency, X-band tube.

In all of these methods, a large magnetic field is needed to keep the beam from spreading due to the strong transverse electric fields. These fields are generally two to five times the field required to focus the beam in parallel flow. In most tubes it is possible to use a high magnetic field over only the electron gun region and taper the field to a much lower value in the circuit region.

An example of what can be achieved by adding several additional electrodes around the cathode is shown by the noise figure curve in Figure 6. These values are approximately one db lower than the best ones obtained in a similar tube without the improved gun design.

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MICROWAVE SUPERREGENERATIVE AMPLIFIERS

J. K. PULFER
RADIO AND ELECTRICAL ENGINEERING DIVISION
NATIONAL RESEARCH COUNCIL
Ottawa • Canada

INTRODUCTION

The use of superregeneration or periodically quenched oscillations for amplifying and detecting radio frequency signals was first introduced by Armstrong in 1922[1]. Early superregenerative detectors allowed the oscillations to build up to saturation during each quench cycle. While this mode of operation (logarithmic mode) provided maximum gain, it did not result in a good communications detector because of its low dynamic range and wide input bandwidth. It was used mainly in applications where small size and low cost were more important than sensitivity and linearity.

During World War II, superregenerative amplifiers were used extensively in I.F.F. transponders. These amplifiers were studied under conditions where the oscillations were not allowed to build up to saturation (linear mode) and the advantages of this method of operation were recognized.[2] With the help of AGC, stable, high gain, linear operation was achieved.

New devices for the amplification of electrical signals at higher and higher frequencies are becoming available. Many of these are in the form of regenerative amplifiers. As a rule, regenerative devices can almost always be made to oscillate reliably at frequencies higher than the maximum frequency of useful amplification. At these upper frequency limits the superregenerative amplifier can be used profitably.

The purpose of this paper is to discuss superregenerative operation of some of the more recent microwave devices such as the backward wave oscillator, parametric oscillator, and tunnel diode which are normally operated as regenerative amplifiers or oscillators.

PROPERTIES OF SUPERREGENERATIVE AMPLIFIERS

A regenerative amplifier may be made into a superregenerative device by periodically varying its loop gain above and below the level required to maintain oscillations. The gain is usually varied electrically, the control signal being referred to as the quench voltage.

To obtain maximum sensitivity, the oscillations must decay to a value below the internal noise of the oscillator during each quench cycle. An external signal introduced into the oscillator feedback loop is amplified when the gain is below that required to sustain oscillation, and determines the initial phase of the pulse of oscillations which subsequently build up. As a result the output spectrum of the superregenerative amplifier consists of a series of replicas of the input signal spaced at the quench frequency. The frequencies of the output lines are determined by the input signal, and not by the oscillator resonant frequency.

If the quench frequency is greater than twice the highest desired component of the signal modulation spectrum, then the signal will be faithfully reproduced regardless of whether the information is contained in AM, FM, Pulses, etc.

By appropriate choice of the quench waveform the superregenerative amplifier may have almost any desired properties although increased bandwidth and stability can be obtained only at the expense of a decrease in noise figure, and increased gain will result in a reduction in dynamic range. Several of the basic properties will be described to aid in the discussion of the performance of various microwave devices as superregenerative amplifiers.

a) *Gain* — The gain of any superregenerative amplifier is approximately the ratio of the final amplitude of the oscillations when buildup is completed to the amplitude of the input signal. Gain depends therefore on the buildup time, the rate of buildup, or (if saturation occurs) on the input signal level and the saturated output of the oscillator.

b) *Dynamic Range* — The dynamic range of a superregenerative amplifier can vary from virtually zero (if the oscillations are allowed to build up from noise level to saturation) to as much as 100 db or greater if the oscillations are allowed to build up only a small amount, say 10 db. Very high gain and large dynamic range can only be obtained by using high power, low noise amplifiers, and in general high power and low noise are hard to find in the same device.

c) *Sensitivity* — The minimum detectable signal depends on the noise figure of the oscillator operating as an amplifier during the period just before and just after oscillations have started, and on the input noise bandwidth. It is quite possible to have a low noise figure, a narrow output spectrum, but a wide input noise bandwidth, and therefore a poor sensitivity. If a superregenerative amplifier is used in a receiver which attempts to detect a modulated signal, then the quench frequency must be at least double the highest modulation component. The input bandwidth, controlled by the quench frequency and waveform, will be somewhat wider than the signal bandwidth, resulting in a degradation of sensitivity relative to a normal amplifier with the same noise figure. Careful shaping of the quench waveform to minimize the excess noise bandwidth is an important part of superregenerative amplifier design.

d) *Output Spectrum* — The output of a superregenerative amplifier consists of a train of pulsed oscillations. Since the phase of the oscillation from pulse to pulse may be coherent or incoherent, the frequency distribution of the output may take the form of a line spectrum or a continuous spectrum. The width and shape of the envelope of the output spectrum is controlled by the width and risetime of the amplifier output pulses as in any other pulse spectrum. The phase of the radio frequency energy affects only the internal structure of the spectrum, not the envelope. If the oscillations are started from internally generated noise, then the phase is random from pulse to pulse, and the output spectrum is continuous. If the oscillations are coherent from pulse to pulse, either due to incomplete decay of the previous pulse when oscillations are initiated or due to the presence of some coherent signal in the oscillator tank circuit which is great enough to overcome internal noise, then the output has a line spectrum. The lines are spaced at intervals equal to the quench frequency. The various output spectra are shown in Figure 1.

e) *Input Bandwidth* — As with any other amplifier, the sensitivity of a superregenerative amplifier is a function of frequency. It may, therefore, be said to have an input or "sensitivity spectrum."

The sensitivity to a signal at any particular frequency will depend on the amount of amplification or attenuation that particular signal has undergone during the time when oscillations are being quenched, and while they are initially building up.

Since the sensitivity spectrum is controlled by the quench voltage waveform before the device is in an oscillating state, and the output spectrum is controlled by the quench waveform when the oscillations are well established and independent of input signals, the input and output spectra are usually different both in shape, centre frequency and bandwidth, and can, to some extent, be varied independently.

Figure 2 is a graph illustrating the various important parts of the quench waveform. Depending on the application of the amplifier, one or more of the sections may be zero.

During the sensitive period, both the gain and the bandwidth of the amplifier vary. The section of the sensitive period in which the gain remains constant is called the "waiting" period. The length of the waiting period in relation to the overall quench period is the most important factor in determining the shape and width of the input noise bandwidth. Two extremes of operation will be discussed.

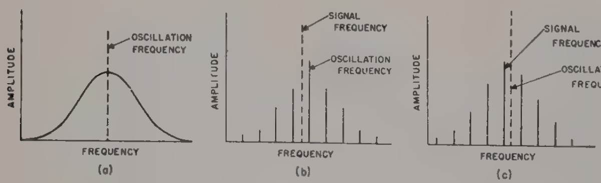

Figure 1 — Output spectra of a superregenerative amplifier for (a) No input signal; (b) Insufficient quenching of oscillations; (c) Amplification of input signal.

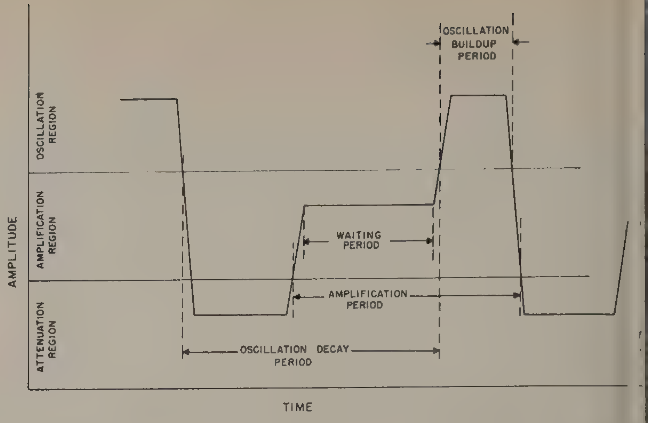

Figure 2 — The important parts of the quench voltage waveform.

a) Wideband

If the length of the waiting period is zero, then the transition from damping to oscillation buildup is very rapid, and the sensitivity as a function of time is similar to that shown in Figure 3(a).[3] The sensitivity falls off rapidly before the peak because of the high damping present, and falls off rapidly after the peak because of the presence of the oscillation which is building up. The corresponding input bandpass, Figure 3(b), is wide relative to the quench frequency, and has a shape determined by the Fourier transform of the sensitivity pulse.

b) Narrow band

If the waiting period is a large fraction of the quench period, and if the gain of the regenerative amplifier is high during the quench period, the sensitivity as a function of time is something like that shown in Figure 4(a). The slopes of the leading and lagging edges of the sensitivity pulse are determined by the damping and by the rate of build up respectively as in the wide-band case discussed above. The slope of the flat top on the pulse is dependent on the gain during the waiting period, and would be zero if the loop gain were unity during that interval. The corresponding sensitivity spectrum is shown in Figure 4(b). The relatively narrow bandwidth and the nulls which appear in the sensitivity spectrum are its most improtant properties. With narrow band operation the input noise bandwidth of the superregenerative am-

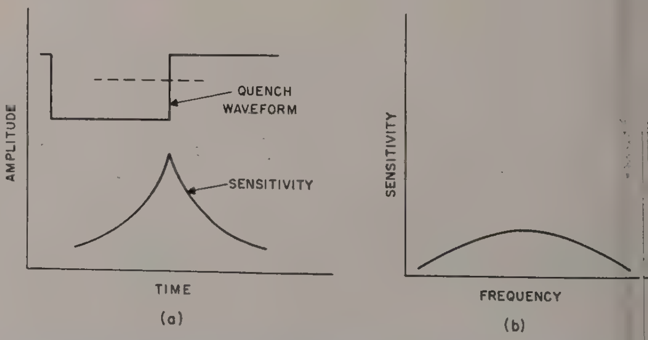

Figure 3 — (a) Sensitivity variation; (b) Input passband for "wide-band" operation.

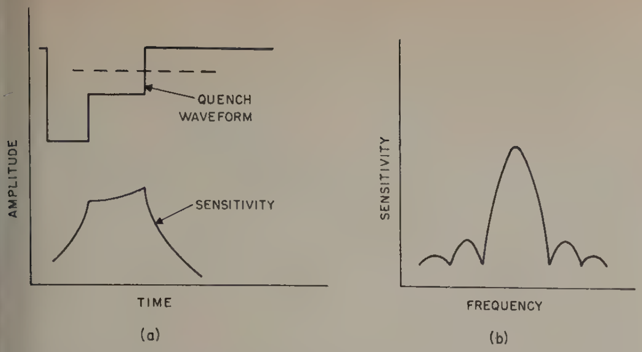

Figure 4 — (a) Sensitivity variation; (b) Input passband for "narrow-band" operation.

plifier need be only slightly larger than that which is necessary to receive modulation on the input signal, and is therefore competitive with other forms of amplifier. If the superregenerative amplifier has an internal nonlinearity so that an output voltage or current may be obtained which is proportional to the envelope of the signal, it is usually referred to as a superregenerative detector.

OPERATION

All five of the properties of the superregenerative amplifiers which are listed above can be controlled by changing the shape and frequency of the quench voltage waveform. Because some of the periods overlap in time, as Figure 2 shows, all of the parameters cannot be optimized independently, and the choice of quench waveform is always a compromise.

To obtain maximum sensitivity when amplifying a modulated signal, the quench waveform should have a waiting period as has been pointed out previously. The complexity of such a waveform limits the maximum quench frequency and therefore the bandwidth of modulation on the signal. If the modulation bandwidth is narrow so that a low quench frequency may be used, stability requirements become more rigid, and some of the advantages of the superregenerative amplifier disappear.

An interesting case in which the quench waveform is synchronized in phase and frequency with a pulsed signal has been discussed by Thomson[4]. Under these conditions very high sensitivities are predicted.

For the most part microwave superregenerative amplifiers are operated with a high quench frequency, usually with a sinusoidal waveform, and the resultant poorer sensitivity is accepted as one of the disadvantages. It should be stressed that the superregenerative amplifier is noisier than the conventional amplifier only because the input bandwidth is wider than necessary for a given modulation frequency. If the receiver is to be used to detect the presence of a CW signal which may be anywhere within a specified bandwidth, then the superregenerative amplifier will perform as well as a conventional type with the same bandwidth. At the upper limits of the usable frequency spectrum the ability to detect a CW signal somewhere in a given bandwidth is a common requirement.

When a superregenerative amplifier is operated at a very high quench frequency, the length of the output pulse is short compared to the buildup time of most oscillators. As a result saturation is not reached, and linear operation is obtained. Lower gain and wider dynamic range result from linear operation. If it is desirable to hold the gain within narrow limits, feedback can be applied to the quench circuitry in most cases.

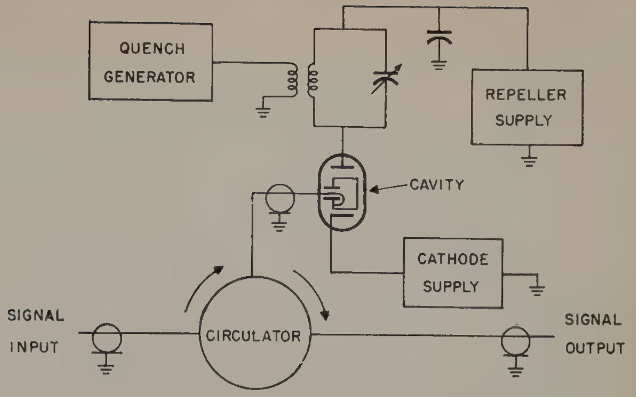

Figure 5 — Diagram of a reflex klystron superregenerative amplifier.

TYPE OF OSCILLATOR

Klystron

Klystrons can be operated as superregenerative amplifiers, and also as superregenerative detectors since the cathode current changes in the presence of a signal. They may be operated with very high quench frequencies if the quench voltage is applied to the repeller because of the rapid damping of oscillations provided by the beam current. As a result, they are more suitable for "wide-band" operation. Klystrons have been operated with a quench frequency of 150 mc/s at Ku band. The principle disadvantage of repeller quenching is the high degree of stabilization required on repeller and quench voltages to keep the gain constant. Figure 5 is a schematic diagram of such a superregenerative klystron amplifier.

Beam current quenching requires more quench power and cannot utilize such high quench frequencies, but voltages are not critical. Although reflex klystrons can be operated as low noise amplifiers[5], superregeneration is not likely to be compatible with low noise operation, because of the critical impedance matches required, and in general, superregenerative klystron amplifiers are characterized by high noise figure and low sensitivity. A good impedance match between the cavity and external circuitry is necessary for optimum performance, and a circulator would improve both stability and sensitivity.

Traveling Wave Tube

A wide-band microwave amplifier such as a traveling wave tube can be operated superregeneratively in several different ways.

The simplest method is to connect the output of the amplifier through an attenuator and narrow-band filter back into the input. Quenching is most easily done by varying the beam current with a control grid. This type of amplifier is an externally tunable narrow band device. The upper limit on quench frequency is set by the ringing time of the narrow band filter. The oscillator may also be quenched by varying the external loop attenuation. Such a system would only be useful in high powered tubes where beam current pulsing would be impractical.

If a very low noise traveling wave tube is used, a high gain, low noise tunable narrow band amplifier is produced. The continuous regeneration control available with grid quenching makes "narrow bandwidth" operation possible.

The second method of using a traveling wave tube is to remove the filter from the external feedback loop, and thus allow oscillations to build up on many frequencies simultaneously across the bandwidth of the tube. If high frequency quenching is used, the oscillations will not be able to build up to saturation, and so the different modes will not suppress one another. This form of operation can produce broadband low noise amplification with considerably higher gain than that available from the tube operated normally. Such an amplifier is shown in Figure 6.

A third method has been described by F. M. Turner[6]. In this system the external feedback path is removed, as well as the internal attenuation of the tube. The results are substantially the same as with the second method, except that the frequency response now depends on reflections from impedance mismatches at the input and output transitions, and in the source and load.

One interesting application of the broadband superregenerative amplifier is in crystal controlled microwave marker generators. A crystal controlled quench oscillator at 50 mc/s can be used to quench an S-band traveling wave tube: harmonics of the quench voltage generated internally on the beam current are amplified superregeneratively and are available at the TWT output.

Crossed Field Tubes

Both magnetrons and M-type backward wave oscillators have been operated superregeneratively. In both cases, the very high internal noise generated by these tubes made the sensitivity so low that it was difficult to get a coherent output spectrum. As superregenerative amplifiers, all M-type tubes operated to-date have proved to be very low in sensitivity.

O-type Backward Wave Oscillators and Amplifiers

Backward wave devices are particularly well suited to superregeneration. Since the "resonant circuit" is present only when beam current is flowing, oscillations can decay very quickly when the beam current is removed. The main factor determining decay time in a backward wave oscillator is the impedance match between the delay line and the output circuit. With a well matched transition, high quench frequencies are easily obtained.

If a backward wave amplifier is used in the superregenerative linear mode with automatic gain control, the dependence of starting current on frequency is not a critical factor for voltage tuned operation as it is when operated as a regenerative amplifier. Gain and bandwidth can easily be made very stable. Figure 7 is a schematic diagram of a superregenerative backward wave amplifier.

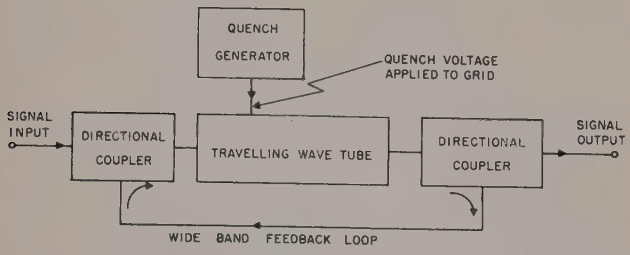

Figure 6 — Diagram of a multimode traveling-wave tube superregenerative amplifier.

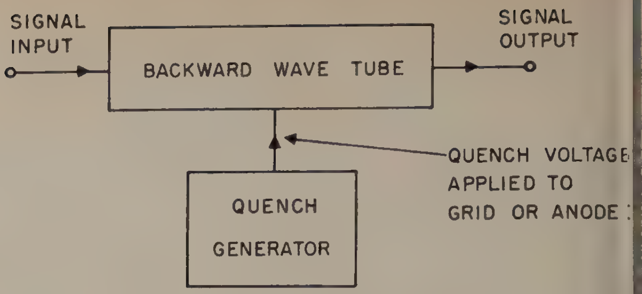

Figure 7 — Diagram of a backward-wave superregenerative amplifier.

A further advantage of the backward wave amplifier is that since it is a traveling-wave device, if the output is properly terminated there will be negligible power reradiated from the antenna. There are many situations where the reradiation from a superregenerative amplifier prohibits its use. A backward wave superregenerative amplifier does not have this problem. Because of the good electrical control over regeneration and the fast decay, both "wide-band" and "narrow-band" operation are possible.

Parametric Oscillators

A superregenerative amplifier made from a degenerate parametric oscillator has several interesting properties. If it is quenched by varying the amplitude of the pump signal, then the phase of the oscillations are not free to build up randomly as in a normal superregenerative amplifier, but must start with one or the other of the two permissable phases. When a signal is inserted into the amplifier both a signal and an idler set of lines appear in the output spectrum.

Figure 8 is a block diagram of an unusual amplifier circuit. The parametric amplifier is quenched by quenching the pump oscillator, so that the pump becomes a superregenerative amplifier and the phase of the pump oscillations becomes random. The output spectrum in the presence of a signal consists of a set of lines for the signal output spectrum, plus a continuous band of noise for the idler output spectrum. If a portion of the amplified signal is fed into a frequency doubler and the re

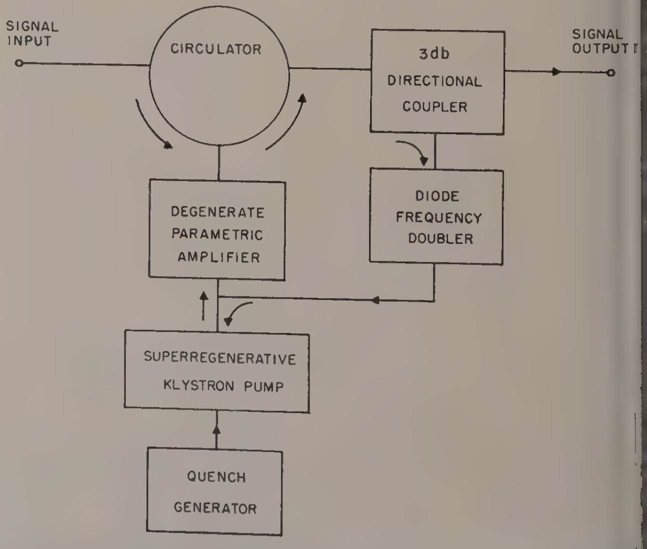

Figure 8 — Block diagram of a superregenerative parametric amplifier with a superregenerative pump source.

sultant second harmonic fed into the pump (which is behaving as a superregenerative amplifier) then the output of the pump will be coherent. The output of the pump will therefore have a component at double the signal frequency, so that the idler and signal will add coherently. The combined superregenerative pump and superregenerative parametric amplifier has a threshold behaviour, and for input signals above this threshold, it suddenly "locks in" and noise virtually disappears.

The parametric amplifier is a low noise device, and, therefore, it is probably worthwhile to operate with a narrow bandwidth and carefully controlled quench waveform in some cases. For optimum detection of low duty cycle pulsed signals, however, a superregenerative amplifier will never be completely satisfactory because of its excess noise bandwidth, and should only be used where high gain and simplicity are the most important requirements.

Parametric amplifiers will operate as self-quenched superregenerative amplifiers[7], but as self-quenching means sacrificing the ability to control the quench waveform, it should only be used where the saving in complexity is a primary consideration.

Masers

The author has done no experimental work with superregenerative masers, but some remarks are included here for completeness. As has been pointed out by P. F. Chester et al[8], superregeneration is particularly adapted to 2-level solid state masers since these normally operate intermittently unless some form of mechanical transport of material is used. This type of maser can have no gain during the oscillation decay period, and so the input sensitivity spectrum is controlled principally by the rate of buildup of oscillations. The passband is thus wider than necessary for a modulated signal and sensitivity is lowered. On the other hand, detection of the presence of any signal within the passband, whether it is noise or a CW signal, can be done as well with a superregenerative as with a regenerative maser, and considerably more gain and stability are obtained at the same time.

If a 3-level solid state maser or a gaseous maser is used, the gain can be smoothly and continuously controlled from zero right up to oscillation. It is, therefore, possible to operate such a maser with amplification during the quenched period, and therefore with a sensitivity spectrum which is only slightly wider than that necessary, and so a good noise figure can be achieved.

A maser may be quenched by varying either the magnetic field, the cavity Q, or the pump power. Variation of pump would seem to be the simplest method. The long time constants associated with oscillation buildup and decay in masers requires that the quench frequency be much lower than in other microwave devices. The use of superregeneration with a carefully controlled quench waveform to obtain high gain, low noise, and good stability, seems to be quite practical.

Tunnel Diodes

One of the most unusual regenerative amplifiers to appear recently is the Esaki tunnel diode. Its low noise, low power requirements, small size and weight, and ultimately low cost, coupled with good high frequency performance make it an excellent microwave amplifier for many purposes. The gain can be varied by changing the dc bias on the diode or by loading the resonant circuit[9]. A second tunnel diode operating as a pulse generator can provide external quenching with simple circuitry. Such an amplifier is shown in Figure 9. The amplifying diode can be self-quenched by making it operate simultaneously as an amplifier and as a pulse generator, but this is not recommended since it does not allow much control over the quench waveform. Build up and decay times for tunnel diode oscillators are very short, especially if the diode is operating as a relaxation oscillator, and therefore quench frequencies can be high, and amplifier bandwidth broad. Superregenerative tunnel diode amplifiers have been constructed in the laboratory, and found to give high sensitivity and stable performance for very little circuit complexity and power requirements. Since the gain cannot easily be continuously controlled by varying the operating potential without the danger of introducing some extraneous frequency modulation, the ultimate noise figure of the diode cannot be achieved when detecting modulated signals. Nevertheless, the performance is considerably better than many electron tubes of much higher cost.

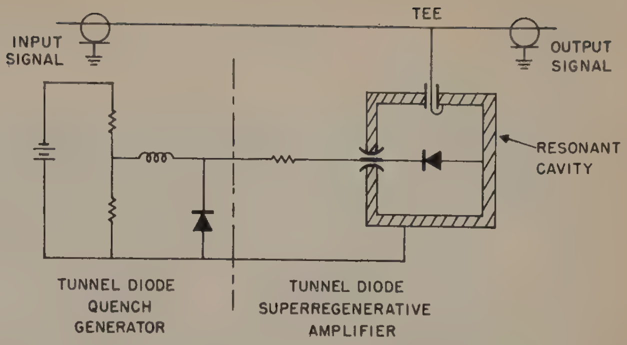
TEE
INPUT SIGNAL
OUTPUT SIGNAL
RESONANT CAVITY
TUNNEL DIODE QUENCH GENERATOR
TUNNEL DIODE SUPERREGENERATIVE AMPLIFIER

Figure 9 — Schematic of a tunnel diode superregenerative amplifier.

Applications

At very high microwave frequencies where other types of amplifiers will not give satisfactory results, a superregenerative amplifier may be used.

Figure 10 is a block diagram of the familiar superregenerative receiver. In this case, a low power backward wave tube is used, and need only have sufficient output power to override the noise in a crystal detector.

The superregenerative receiver has the advantages of higher gain, wider bandwidth, and increased stability over the regenerative form of backward wave amplifier. It has the advantage over a superheterodyne receiver of requiring only microwatts instead of milliwatts of power at the received frequency, and is also considerably simpler. As pointed out earlier, if the frequency indeterminacy of the

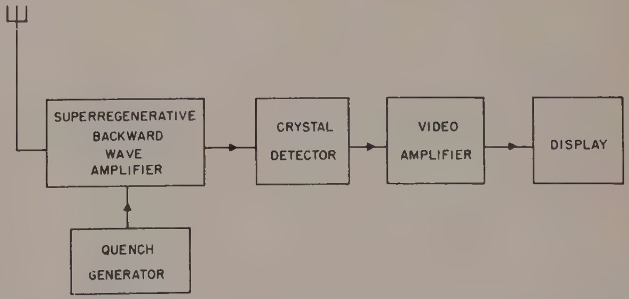

Figure 10 — Block diagram of a superregenerative receiver suitable for use at very high microwave frequencies.

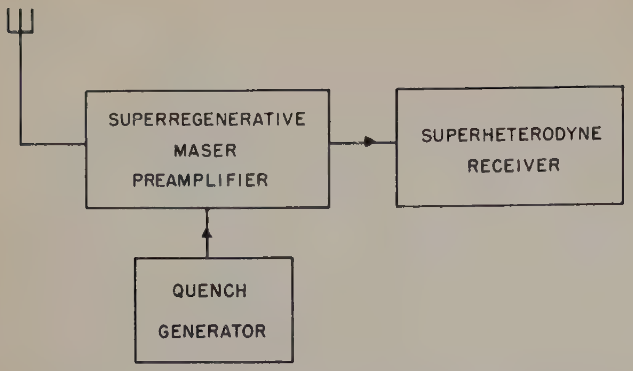

Figure 11 — Block diagram of a superheterodyne receiver using a superregenerative maser pre-amplifier.

received signal is several times its modulation bandwidth then the superregenerative receiver is at no disadvantage with respect to sensitivity.

A second example is an application where an increase in bandwidth, gain and stability are desirable, and where some sensitivity may be sacrificed.

Figure 11 is a block diagram of a superheterodyne receiver using a low noise superregenerative maser preamplifier. There are many applications where the noise contributed by the maser amplifier is a very small part of the over-all receiver noise, and increased bandwidth would be desirable at the cost of a slight increase in noise figure.

A third application of superregenerative amplifiers is in light weight low power microwave transponders.

Figure 12 is a block diagram of a tunnel diode transponder which could easily provide a gain of 40 or 50 db with a bandwidth of several tens of megacycles at S-band. It should be emphasized that such a device will work as well as a pulse transponder as for other forms of modulation, providing that the quench frequency is sufficiently high.

If the tunnel diode is replaced by a traveling-wave amplifier with a wide-band feedback loop, it can have the additional property of being able to operate over a very wide passband.

CONCLUSIONS

Superregeneration is a useful microwave technique. When applied to most of the common negative resistance or regenerative amplifiers, it results in wide bandwidth, good linearity, and increased stability.

The greatest potential application of superregenerative devices is the amplification of signals whose frequency is not accurately known. If the frequency indeterminacy is several times the modulation bandwidth of the signal then the superregenerative amplifier can compete in sensitivity with conventional amplifiers.

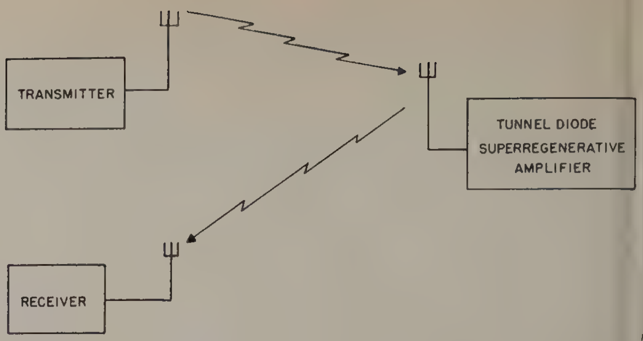

Figure 12 — Block diagram of a tunnel diode transponder.

If the desired input bandwidth is less than a few megacycles, the quench waveform can be carefully controlled resulting in a minimum excess bandwidth and maximum sensitivity. In doing so, however, the stability and simplicity are lost, and there is really little advantage over a regenerative amplifier.

Some of the newer microwave devices, such as masers and parametric oscillators, are particularly well suited to superregenerative operation, and performance characteristics can be obtained which are not normally expected in these devices.

ACKNOWLEDGMENTS

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FREQUENCY INDEPENDENT ANTENNAS —

Several New and Undeveloped Ideas

C. W. GILLARD
R. E. FRANKS

ELECTRONIC DEFENSE LABORATORY
Mountain View • California

INTRODUCTION

There can be little doubt that frequency independent antennas — antennas that display little or none of the usual impedance and pattern dependence upon frequency above a certain low frequency limit — are having a decided impact upon the scope and versatility of communication channels of an advanced nature. Future space communications systems, and in particular the use of satellites as communication devices, point up a rather urgent need for both high gain and low gain frequency independent antenna systems. Access to the extreme ends of the gain spectrum by way of frequency independent antennas (constant impedance and pattern) is the main topic of this paper.

To give the subject matter perspective it would be well to first consider the portion of the gain spectrum available with existing frequency independent antennas. The merits of this point of view should be clear from Figure 1, which was generated from available data on log-periodic and equi-angular antennas. The values indicated in the figure are indicated to be approximate.

Referring to the figure, bands of low gain (0 db — 5 db), medium gain (5 db — 20 db) and high gain (20 db — ∞) have been arbitrarily designated. As far as is known, frequency independent antennas capable of operation in the shaded end-regions of the gain spectrum are not within the state-of-the-art. We exclude the biconical antenna and its derivatives, as their patterns show appreciable variation over multi-octave bandwidths.

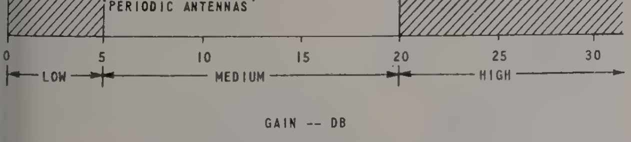

Figure 1 — Gain spectrum available with existing frequency-independent antennas.

From an intuitive point of view one might come to the general conclusion that a frequency independent technique applicable to aperture type antennas should be sought for the high gain region of the gain spectrum and that a frequency independent dipole would be appropriate for the low gain region of the spectrum.

Medium gain, frequency independent antennas are not considered in this paper as many successful achievements and considerable development effort has resulted in a wide choice of practical antennas in this domain.

HIGH GAIN FREQUENCY INDEPENDENT ANTENNA SYSTEMS

High gain antenna systems displaying little or none of the usual pattern dependence upon frequency have long been sought for such applications as broadband tracking, constant angular area surveillance, or communications systems.[1] But it is well known that for high-gain apertures the half-power beamwidth or pattern width at any given reference level varies approximately inversely with frequency or linearly with wavelength. Any mechanism employed to prevent this variation must necessarily involve some means of controlling the antenna aperture, amplitude distribution, phase distribution, or a combination of both, as aperture amplitude and phase uniquely determine the pattern of aperture type antennas.

Pattern stability by way of any kind of phase variation in an aperture is essentially a problem in variable beamshaping. The only feasible mechanism visualized and briefly investigated whereby this might be achieved employed a beamshaping doublet lens system, one element of which was dispersive. Essentially, the idea was to progressively bend the phase front of a nominally equiphase aperture; it was expected that increasing the bending with frequency, if done properly, would broaden the pattern and thus compensate for the usual inverse pattern-frequency dependence. However as Brown[2] points out, beam-shaping lenses have not as a rule proven satisfactory due to multiple reflection effects within the lens system.

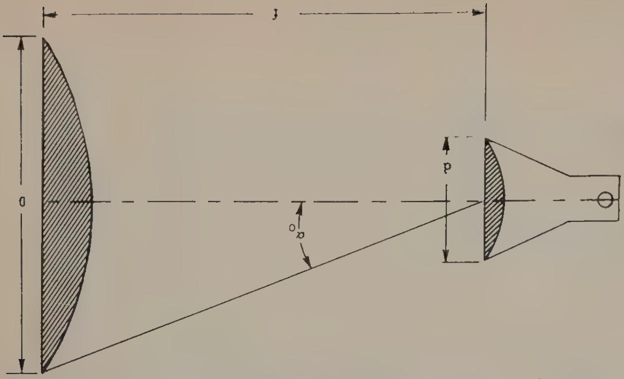

Figure 2 — Two-dimensional version of high-gain, frequency-independent antenna system.

Attempts to employ such techniques as defocusing and reflector beamshaping have also been investigated briefly and found to be both complicated and wanting in desired bandwidth properties.

Antenna pattern stability by means of regulating the amplitude distribution in an equi-phase aperture has been investigated and demonstrated to be quite feasible, but at some sacrifice in nominal aperture efficiency at the low end of the intended frequency band.

Elementary Aperture Amplitude Controlled Frequency Independent Antenna

Rudiments necessary to a basic understanding of a high gain, aperture amplitude controlled, frequency independent antenna are illustrated by Figure 2. The primary feed of the system should be considered simply as an equi-phase aperture with fixed illumination which, as is well-known, will provide a pattern with a beamwidth (or angular width at any reference level) directly proportional to wavelength. Thus, providing the angle α_0 is not too large, the amplitude distribution at the collimating aperture measured in terms of wavelength is constant and gives rise to a frequency independent pattern.

It is important that the collimating aperture receive nearly all of the main lobe from the primary feed in order that the relative effective aperture distribution remain essentially independent of frequency. This restriction is effective at the low frequency end of the band λ_l and is expressed in terms of the parameters shown in Figure 2 by

$$\alpha_0 = \sin^{-1} \frac{D}{\sqrt{4f^2 + D^2}} \doteq \sin^{-1} K \frac{\lambda_l}{d} \, . \qquad (1)$$

The constant K depends upon the illumination function of aperture d and also upon the level of illumination intensity chosen for the edge of aperture D at this wavelength, λ_l. If the first nulls of the primary feed pattern are set on the edge of aperture D and the aperture illumination across d is a cosine function,[3] K will equal 1.5. This is unnecessarily restrictive, however, and some spillover of the illumination of aperture D may be allowed. Assuming that edge illumination of aperture D may be allowed to rise to the 10 db point on the primary feed main lobe at the long-wave-length limit, then with cosine illumination of aperture d, K will be approximately unity.

Solving Equation (1) for λ_l.

$$\lambda_l = \frac{D\ d}{K\sqrt{4f^2 + D^2}} \simeq \frac{Dd}{2Kf} \text{ if } f > D. \qquad (2)$$

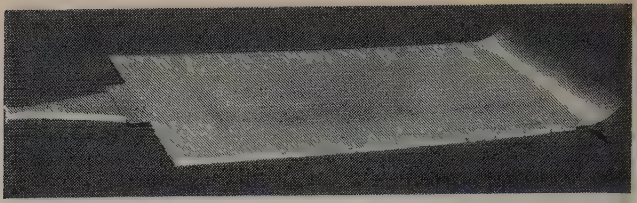

Figure 3 — Two-dimensional embodiment of a frequency-independent antenna.

It might be expected that an upper frequency limit woul exist because at sufficiently high operating frequencie the primary feed no longer appears as a point source a the focal point of collimating aperture D. This limit ma not occur, however, as can be shown by consideration o the form of the secondary pattern as the operating wavelength approaches zero: in the optical limit, the apertur distribution of d would be projected at infinity by lens D The secondary beamwidth between nulls would then b approximately d/f. At the wavelength near the long wavelength limit where the primary feed main lobe jus fills aperture D, the secondary beamwidth between null will be $3\lambda/D$.

However, under these conditions, as was show earlier by Equation 2, $\lambda_l \frac{Dd}{2(1.5)f}$. With this value o λ_l the secondary null beamwidth $= 3\lambda/D =$ $3\,\frac{Dd}{3f}\cdot\frac{1}{D} = d/f$, which is equal to the optical lim case, or where $\lambda \rightarrow 0$. It has been shown that, at least f cosine primary linear aperture distribution, the secondar pattern is essentially the same for an operating wavelength near the longer limit as it is for wavelengths approaching zero. The degree of variation within the limits will be evident later.

Corroborative Results — Experimental Patterns

The first antenna system employing the aperture amplitude control techniques discussed was the two-dime sional device illustrated in Figures 3 and 4; two-dime sional geometry was employed in deference to a limite budget. This device, not intended to provide wideban coverage, was used to demonstrate the feasibility of th idea. At $f_0 = 6.65$ kmc, the edge illumination of th large aperture is approximately 10-db. Patterns o

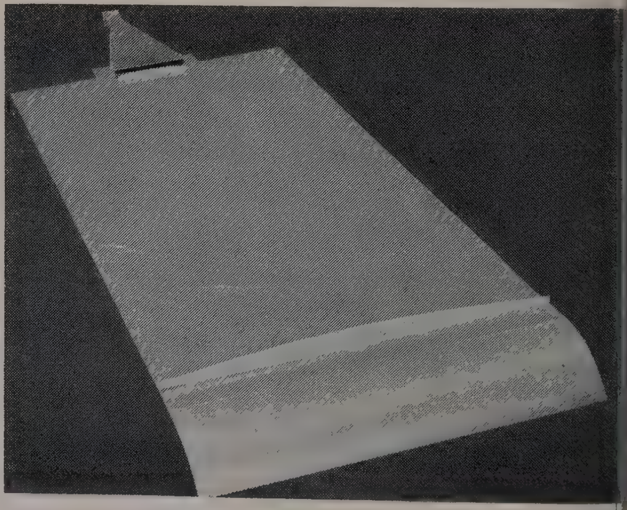

Figure 4 — Perspective view of two-dimensional frequen independent antenna with top plate removed.

tained over a 1.6:1 band are shown in Figure 5 and illustrate an essentially frequency independent main lobe. Extending this technique in three-dimensional antennas will be considered later.

Corroborative Results — Computed Patterns

In an attempt to obtain a better correlation between useful bandwidth and antenna geometry, patterns of the two-lens system in Figure 6 were taken via an IBM 650 computer. As before, a reference wavelength λ_o was chosen such that edge illumination of the collimating aperture is approximately 10-db. Defining a parameter

$p = \frac{\lambda_o}{\lambda} = f/f_o$, patterns of the antenna system shown

in Figure 6 were computed over a range $0.5 \geq p \geq 30$. In terms of λ_o, the dimensions of the system were chosen to give the model the proportions of a practical antenna:

$$\frac{d}{\lambda_o} = 4;\ \frac{D}{\lambda_o} = 20;\ \frac{f}{\lambda_o} = 40\ .$$

Following Silver,[4] assuming that the antenna is two-dimensional, the field at point P is given by

$$U(P) = \frac{1}{4\pi}\int_A \frac{F(\xi)\ e^{-ikr}}{r}\left[\, jk + \frac{1}{r}\ \hat{Z}\ .\ \hat{r} + jk\ \hat{Z}\ .\ \hat{S}\,\right] d\xi$$

where $F(\xi)$ is the illumination over aperture A, and $K = \frac{2\pi}{\lambda}$, λ being the wavelength. If we use Silver's Fresnel Zone approximations, measure distances in terms of λ_o and normalize to $U(P_o)$, $P_o = (0,f)$, we get

$$U_o(P \text{ on } C) = \frac{(1+\cos\alpha)\int_A F(\xi)e^{j2\pi p\left[\xi \sin\alpha - \frac{\xi^2}{2f}\right]}d\xi}{\int_A F(\xi)e^{-j\pi \frac{P}{f}\xi^2}d\xi}\ .$$

Silver's approximations are valid in the case presented here. We now make one further assumption which is reasonable in this geometry: that U(P on C) differs only negligibly from U(Q on B) after the wave passes through lens B, Q being the intersection of line OP and aperture B. The Fraunhofer field of aperture B, normalized, is given by

$$V_o(\theta)\quad \frac{\int_B U[Q(x)]e^{j2\pi x \sin\theta}dx}{\int_B U[Q(x)]\ dx}$$

The approximation that $U(P) \approx U(Q)$ was used to simplify the computations and is quite good for small α, say 15 degrees and less.

U_o(P on C), $V_o(\theta)$ and $P'_o(\theta)$, the final power pattern, were computed for p = 0.5, 0.75, 1.0, 1.4, 3.875, 11.5, 30 using $F(\xi) = \cos\frac{\pi\xi}{d}$. These results are presented in Figures 7 and 8.

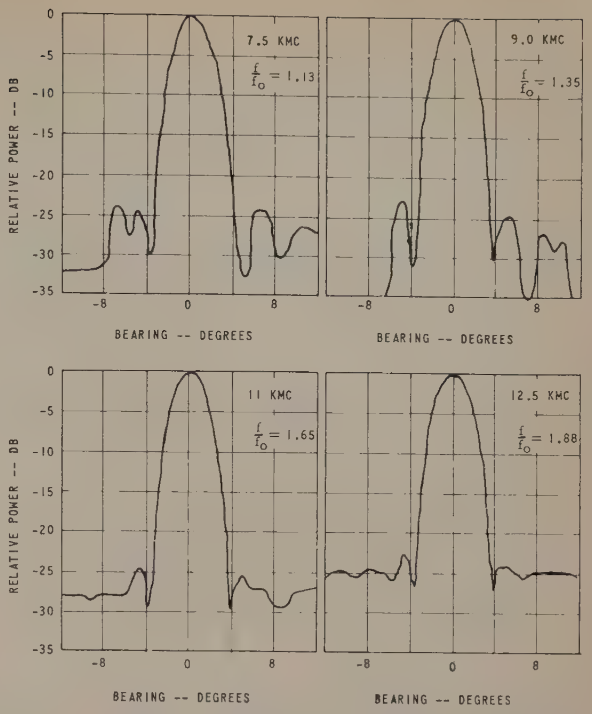

Figure 5 — Patterns obtained with two-dimensional antenna.

While highly efficient methods (from the standpoint of computing) for evaluating the double integrals in $V_o(\theta)$ are well known, they were evaluated separately so that plots of $U_o(Q)$ across B could be prepared. The integrals in $U_o(Q)$ were evaluated in terms of Fresnel Integrals, using the usual method of completing the square in the exponent of the integrand. The values of α for which U_o(P on C) was evaluated were obtained by $\alpha_i = \tan^{-1}\frac{x_i}{f}$, the x_i being equally spaced across B at

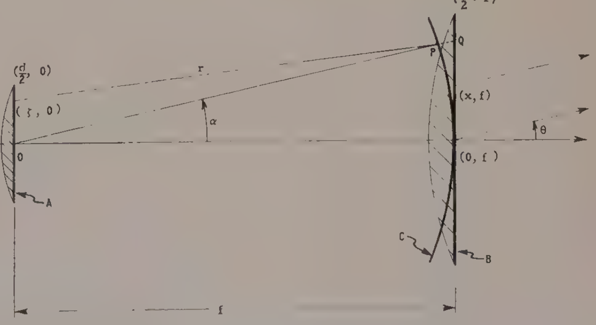

Figure 6 — Double-lens geometry used in machine calculation.

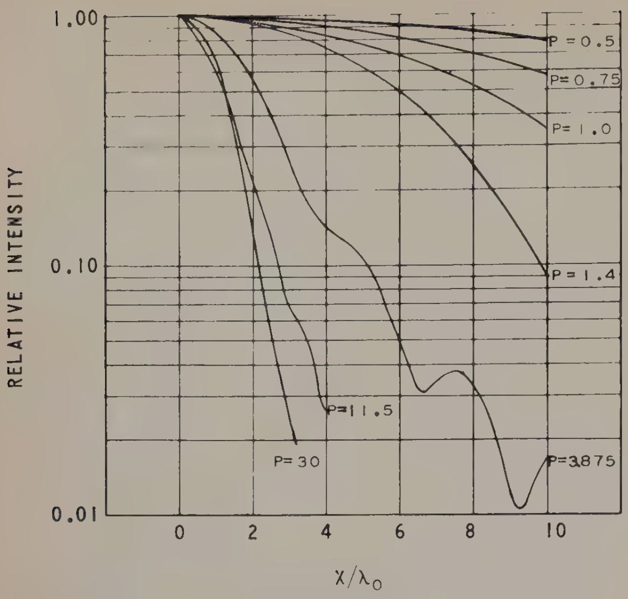

Figure 7a — Second aperture illumination.

close enough intervals to assure accuracy in the final integration.

The computed patterns in Figure 8 show that the low frequency limit of pattern constancy occurs near the frequency (p = 1) at which the collimating aperture edge illumination has risen to 10-db. Patterns computed at frequencies greater than this lower limit are almost identical, and indicate that, for the chosen dimensions, the optical limit is approached with small pattern perturbation as a function of frequency.

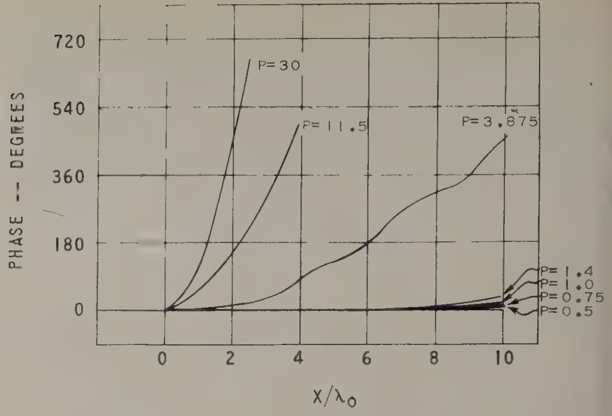

Figure 7b — Second aperture phase angle.

Potential Applications

Utility value of the high gain frequency independent antenna concept perhaps can be illustrated best by a brief consideration of a few possible antenna configurations employing the principle. For example, a biconical antenna system consisting of a lens-corrected biconical horn feeding a large toroid lens would provide a means of obtaining frequency independent omnidirectional coverage — an antenna with considerable potential in broadband communications or surveillance applications. Such a system might appear as illustrated in Figure 9.

Figures 10 and 11 illustrate methods that might be employed to obtain broadband, frequency independent pencil beam patterns. The primary feed mechanism — a parabolic dish or lens with a log periodic feed — has already been developed and can be designed to provide the

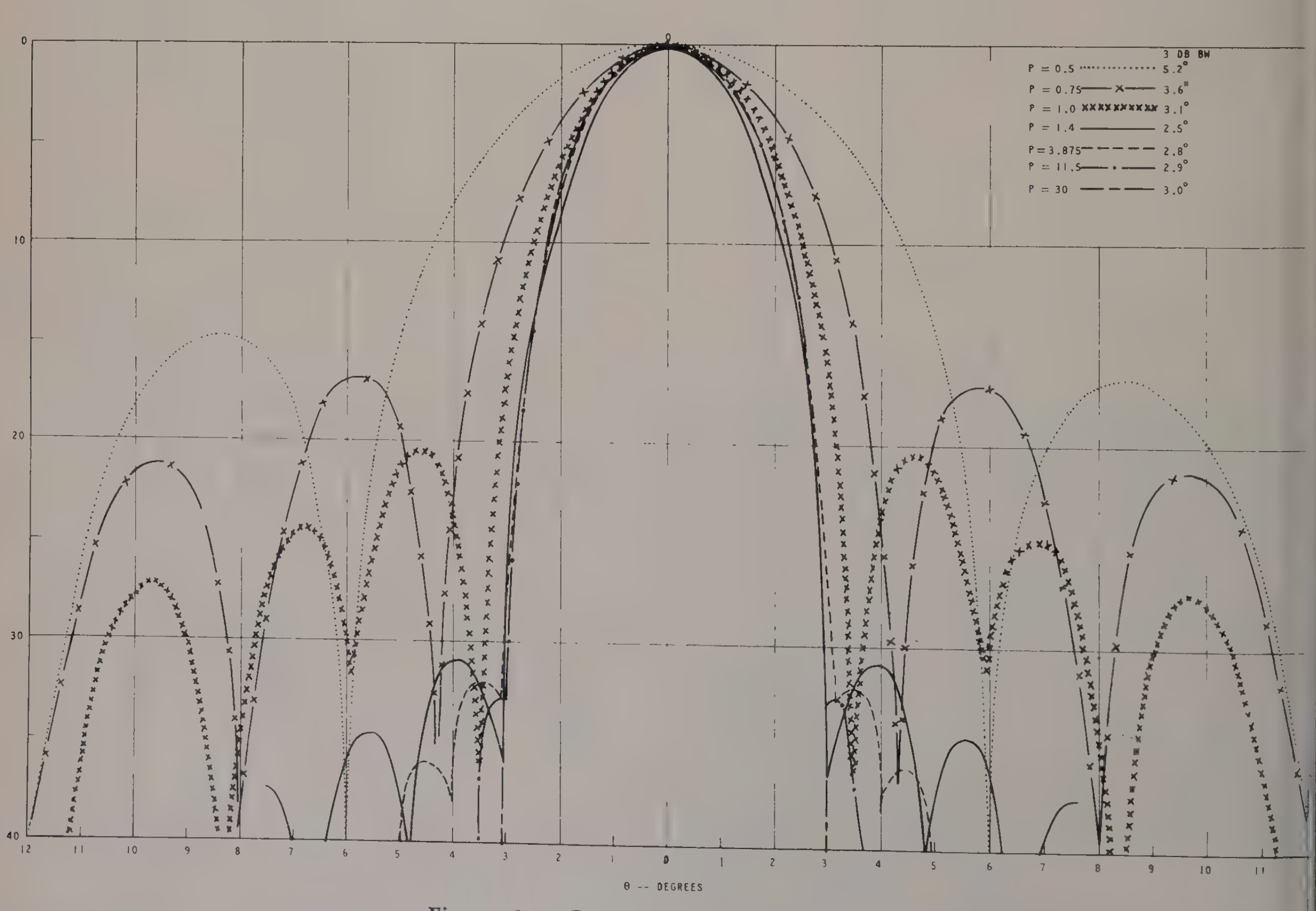

Figure 8 — Computed secondary patterns.

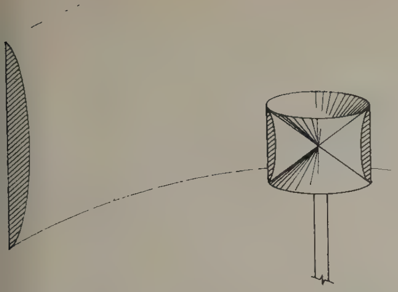

Figure 9 — Cross section of frequency-independent bi-conical antenna system.

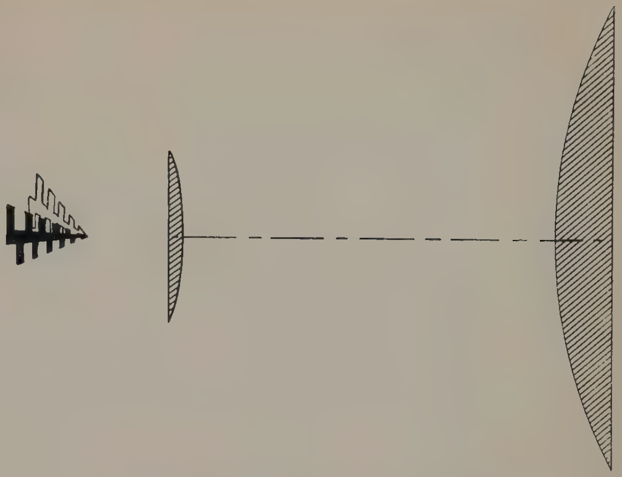

Figure 10 — Pencil-beam frequency-independent antenna using dielectric lenses.

necessary pattern characteristics over a 10:1 frequency band.[5]

In either of these applications, high sidelobe illumination of the collimating aperture by the primary feed system may be expected to cause significant pattern perturbation, and may place requirements on the illumination taper of the primary feed aperture. The linear aperture case analyzed was not greatly perturbed by the sidelobes of the primary aperture; however, the three-dimensional antenna configurations may be expected to present greater problems.

An interesting although somewhat academic interpretation can be made of the frequency independent antenna illustrated by Figure 10. If we encase the two-lens system in the usual electronic "black box," we see that the black box may be considered as a transformation device, transforming the low-gain frequency independent pattern of the log-periodic antenna to a high-gain frequency independent pattern. With this concept one might ponder various schemes for altering the parameters of the black box without changing its function — such as decreasing its axial dimension, for example.

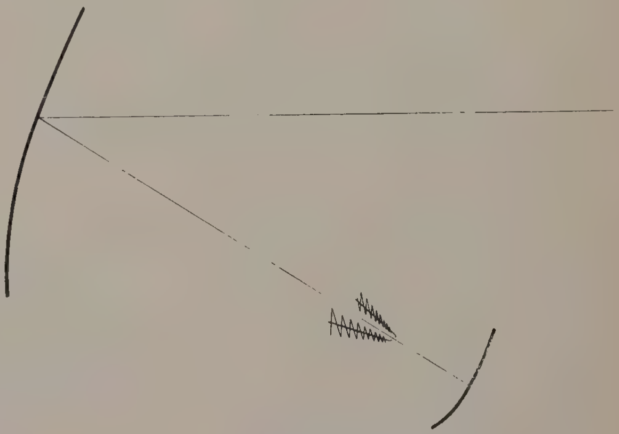

Figure 11 — Pencil-beam, frequency-independent antenna employing parabolic reflectors.

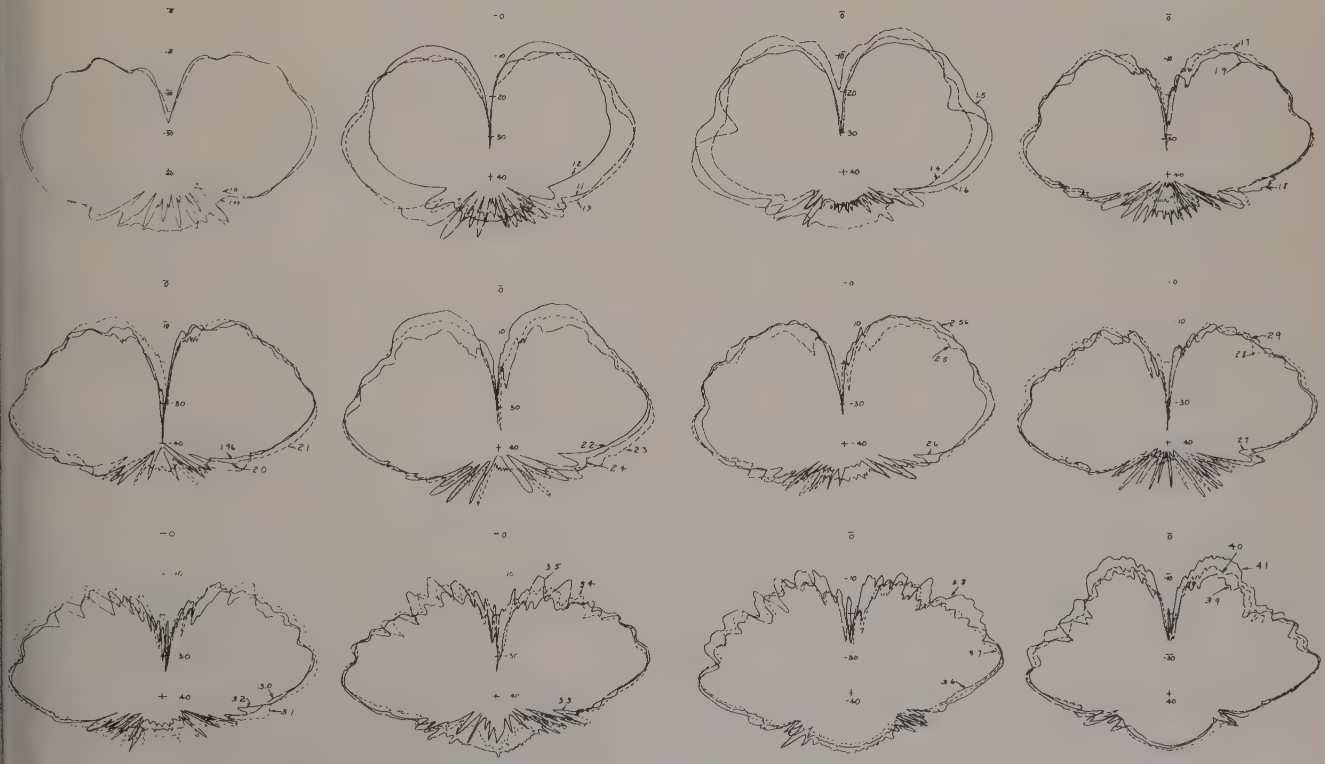

Figure 12 — Patterns of log-periodic element over a two octave frequency band.

LOW GAIN FREQUENCY INDEPENDENT ANTENNAS

Mention of the low gain frequency independent antenna is purposely brief as it is to be the topic of a future paper.

Stemming from a desire to eliminate the antenna tuning black box usually placed at the base of vertical whip communications antennas, the need for a simple antenna giving a low gain, wide angular coverage pattern has been recognized for many years. Musing upon feasible ways to solve this problem leads one to the reasonable conjecture that some form of dipole embodying the log-periodic broadbanding principle — a log periodic dipole — might provide a likely way to achieve such a goal. For example, if a continuous distribution of reactive elements deployed along the axial length of a long monopole could be made to cause a large impedance discontinuity (anti-resonance) to occur in such a manner that the axial position of the discontinuity varied linearly with wavelength, a standing wave should form which would give rise to antenna pattern and impedance characteristics that are independent of frequency. One means of approximating such a structure is provided by a log-periodic progression of loaded quarter-wave chokes.

The degree of progress achieved to date with the log-periodic monopole is indicated by the data presented in Figures 12 and 13. Unfortunately the performance of the structure as an antenna is not as desirable as the data indicate: it was necessary to introduce loss in the chokes to control a violent periodic behavior in both pattern and impedance. As a result the structure is a rather inefficient antenna: efficiencies as low as 25 per cent over some regions of the frequency spectrum were experienced. Strong correlation between the cyclical nature of both the pattern and impedance data and the log-periodic constant employed to generate the structure is present, a characteristic property of the log-periodic antenna.

CONCLUSION

A frequency independent technique appropriate to high gain aperture type antennas appears to be quite feasible. High sidelobe illumination of the collimating aperture by the primary feed system may be expected to cause significant pattern perturbation for some embodiments of the idea and must be resolved before the method becomes a practical reality.

At the low end of the gain spectrum the application of the log-periodic broadbanding principle to the dipole is a highly desirable objective; however, experimental results to date indicate that a more fundamental approach is necessary. If successfully developed, the log-periodic dipole would in turn provide the basis for an entire new generation of broadband antenna structures, as the dipole is a basic antenna building block.

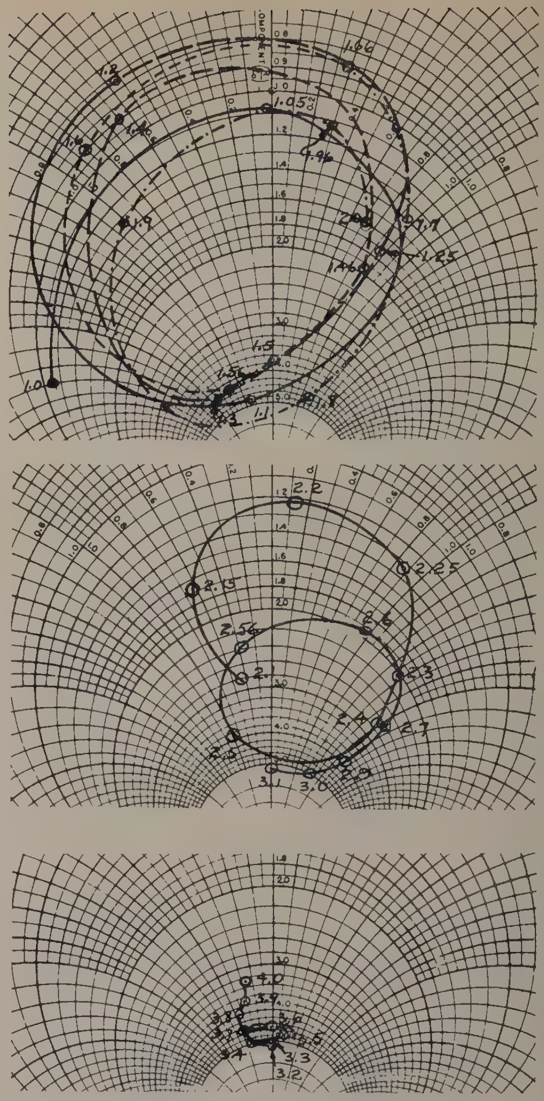

Figure 13 — Impedance of log-periodic element over a tw octave frequency band.

ACKNOWLEDGMENT

The authors wish to express their appreciation for th efforts of Mr. John Downey who computed the patterns o the two-lens system and kindly prepared a resume of hi analysis for this paper and to Mr. S. Miller and Mr. C Kiernan for design and implementation of the experimental effort.

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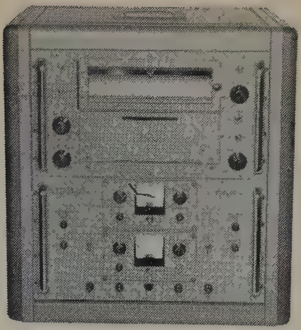
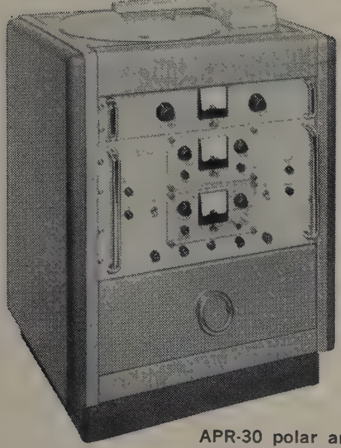
5. R. H. DuHamel and F. R. Ore, "Log-Periodic Feeds fo Lens and Reflectors," 1959 IRE National Convention Record, p. 128.

* * *

Flexibility and Refinement



APR-20 rectangular antenna pattern recorder

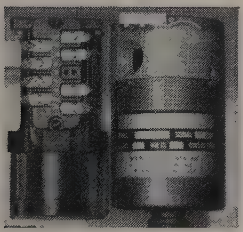


APR-30 polar antenna pattern recorder

...The reason most antenna pattern recorders come from S·A

It's the little things that make the difference. Little things, refinements, "extras," and top-notch workmanship all add up to preference for S-A instrumentation.

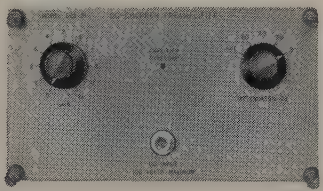
Things Like Plug-In Balancing Potentiometers...



Series P plug-in pen balancing potentiometers

Series P potentiometers are used in both rectangular and polar coordinate pattern recorders. By interchanging potentiometers together with the appropriate pen function amplifier, different responses—linear, square-root, and logarithmic—are obtained. Interchanging these new self-aligning potentiometers can be accomplished in less than thirty seconds. Stocking spare units cuts downtime. Of dust and dirt proof construction, Series P plug-in balancing potentiometers are offered with exchange pricing.

DC Amplifiers...



DCA-21 amplifier for dc input signals

Scientific-Atlanta's DCA-21 amplifier lets APR 20/30 recorders accept dc input signals. A narrow band amplifier preceded by an electromagnetic chopper, the sensitive DCA-21 has a linear dynamic range of 80 db. The unit is directly interchangeable with Series CBA-20 Crystal-Bolometer amplifiers.

Recorder Pen Programmers...

Up to five different pen writing codes can be selected by adding the Model RPP-1 Recorder Pen Programmer to an APR 20/30 installation. Compact, lightweight, and rack mounted, the programmer provides solid line, dot, dash, dash-dot, and space-dot-dot codes at an adjustable code rate of 30 to 90 cycles per minute.

Modification C, Chart Compression...

Modification C, which must be ordered at the time of recorder purchase, provides both standard and compressed cycle charts from a single APR 20 Rectangular pattern recorder. Standard chart cycle is 20 inches, compressed 8 inches. Compressed recordings are conveniently sized to fit standard 8½ x 11 notebooks and reports.

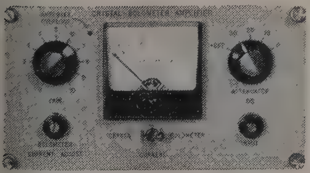
Chart Paper, Recording Pens, Ink, and Accessories...

Scientific-Atlanta offers its customers one-day service by stocking, for immediate delivery, a wide variety of chart paper, recording pens, and other recording necessities.

But above all, it's the engineering philosophy of a company run by antenna engineers for antenna engineers.

Call your nearby S-A engineering representative for more information on S-A pattern recorders and accessories. For complete technical information, please write to Box 69

Crystal Bolometer Amplifiers...



High gain, low noise crystal-bolometer antenna

Sensitive, narrow-band Crystal-Bolometer amplifiers are miniaturized units designed for use as preamplifiers in S-A polar and rectangular pattern recorders. Five models, CBA-21 through CBA-25 are available. Features include bolometer burnout protection, low noise figure, triaxial signal ground return, up to 108 db gain, 80 db linear dynamic range, adjustable bandwidth (CBA-23), high rejection (CBA-24), variable center frequency (CBA-25).

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7

The Mesh Cathode

AN ITT BREAKTHROUGH IN RADAR SWITCH TUBE DESIGN

This seemingly delicate web of wire is actually the most rugged and structurally stable construction ever developed for power tube cathodes. Consisting of a fine cylindrical mesh instead of the usual filament configuration, the exclusive ITT mesh cathode is now available in a number of high-performance pulse triodes and power diodes. The triodes are specifically designed for radar switching applications; the diodes are ideally suited for rectifier, clipper and charging service.

Mesh cathode construction, in addition to its mechanical advantages, offers improved emission per watt in comparison with conventional cathodes, as well as quick heating and superior temperature stabilization. The cylindrical design results in an emission pattern that uses more of the available grid surface and thus reduces grid emission problems. This latest ITT power tube "first" is probably the closest existing approximation of a theoretically ideal "physicist's cathode."

Write for information on the complete line of ITT pulsed modulator triodes and power diodes. Application assistance is available for your specific requirements.

MODULATOR TRIODES – PULSED OPERATION

TYPE	PULSE POWER OUTPUT [1] (kw)	D-C PLATE VOLTAGE (kv)	PULSE CURRENT [1] (amperes)	PULSE CURRENT [2] (amperes)
F-7206	2200	18	220	350
F-7328	900	20	100	160
F-7839	7800	65	160	230
D-1037	30000	65	650	1000
F-6920	4100	35	140	200
F-7012	90	18	40	65

[1] At rated filament voltage
[2] At elevated filament voltage

HIGH VACUUM POWER DIODES

TYPE	APPLICATION	PEAK INVERSE VOLTAGE (kv)	PEAK CURRENT (amperes)	AVERAGE CURRENT (amperes)
D-1033	Rectifier	60	36	12
	Shunt or Charging	60	150	–
D-1034	Rectifier	50	45	15
	Shunt or Charging	50	200	–
D-1038	Rectifier	40	18	6
	Shunt or Charging	40	100	–
D-1039	Rectifier	65	21	7
	Shunt or Charging	65	100	–

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ELECTRON TUBE DEPARTMENT ■ COMPONENTS DIVISION
INTERNATIONAL TELEPHONE AND TELEGRAPH CORPORATION, CLIFTON, NEW JERSEY

ITT COMPONENTS DIVISION PRODUCTS: POWER TRIODES AND DIODES • IATRON STORAGE TUBES • HYDROGEN THYRATRONS • TRAVELING WAVE TUBES • SELENIUM RECTIFIERS • SILICON DIODES AND RECTIFIERS • TANTALUM CAPACITORS

Circle Reader Service Card 35

(*Continued from page 44*)

RABER JOINS DORNE & MARGOLIN ENGINEERING STAFF

Samuel Raber, a research development specialist, has joined the engineering staff of Dorne & Margolin, Inc., Westbury, L. I., N. Y., as section head of the Circuit Group.

Mr. Raber formerly was associated with Fairchild Astrionics Division as a development specialist in the research division.

Working on the Data Link Transmitter for the USD5 Surveilance Drone at Fairchild, Mr. Raber developed a transistorized wide band voltage controlled oscillator in the 5-10 Mc region and was engaged in a feasibility study to determine a novel ranging system involving the "near field" radiation of a dipole.

Mr. Raber received his BSEE from Union College, Schenectady, N. Y. in 1950, and his MSEE from the University of Maryland in 1957. He is a senior member of the IRE.

—*mwj*—

NARDA MICROWAVE ANNOUNCES PROFIT IMPROVEMENT

Sales and profits of the Narda Microwave Corp., Mineola, N. Y., for the six months ended December 31, 1960 were the highest in the company's history.

Sales for the half year were $1,236,203, a 14 per cent increase over the same period last year. Profits increased more than 100 per cent over the first half of the previous year. The $63,000 net profit after taxes for the six months approximates the net operating earnings of the firm's best previous complete fiscal year.

"Management is particularly pleased that its Profit Improvement Program has begun to show progress and fruitfulness," William A. Bourke, president, said. "The dramatic increase in profits can be attributed to the efforts at every level of the company in an organized program of Profit Improvement."

The results of the past six month's progress in new product development will be featured in Narda's exhibit at the IRE show in March. The company will demonstrate a new line of solid state microwave ferrite devices with high performance factors, a coaxial coupler featuring a major advance in performance specifications, the first broadband direct reading coaxial attenuator on the market, and the latest high power modulator designs.

Narda also has announced an agreement with Axinn & Mascioli, Great Neck, N. Y., to construct a 40,000 square foot plant for lease and occupancy by late summer 1961. The new plant will provide for all of the company's needs under one roof with an eventual capacity approximately double its present volume.

—*mwj*—

(*Continued on page 76*)

The Greeks had a word for it, which escapes us at the moment. And we should have a better word for it, but we haven't. In this day and age, a pedestal is not a simple device to hold something up. Rather, at least in the electronics industry, it is a unique and complex portion of an antenna system.

LET'S TALK ABOUT PEDESTALS

Canoga designs, develops and manufactures rugged, reliable, light-weight, low-cost pedestals for almost any radar and telemetry, optical and infra-red use—land-based, ship-borne, on trailers, on roof-tops; for use in the arctic, in the desert or in the tropics.

Canoga pedestals are slim, minimizing wind loading and permitting the mounting of counterbalances significantly closer, thereby greatly reducing polar moments of inertia. Gear trains and related electronics are completely enclosed—providing protection from weather, fouling, corrosion, breakage, etc. Up to 810° of travel are available without slip-rings for non-rotational tracking and slip-ring models are available for all around tracking capability. (Canoga has developed the Tri-Ped antenna which provides complete flexibility by the addition of a third, or traverse, axis to the conventional azimuth and elevation axes.)

A single stowing lock secures both elevation and azimuth gears and disengages servos in one operation. Elevation of 200° permits "plunging" for boresight purposes.

Canoga pedestals offer compact, double planetary, interchangeable drive modules with eccentric backlash adjustment, modular interchangeable data packages, balanced elevation yoke which eliminates eccentric loading of the azimuth bearing, yielding increased high-elevation angle accuracy and minimizing the perpendicularity problem. Also, a synchro-torque transmitter hand-wheel follow-up feature eliminates unexpected pedestal accelerations when switching from the slaved to local mode of operation.

Canoga pedestals can accommodate paraboloidal dish antennas up to 28' in diameter and various helix arrays.

Standard bolt circle and bolt dimensions provide for adaptability to standard mounts or mounting can be engineered to customer specifications.

Canoga Electronics Corporation also manufactures complete radar systems, microwave ferrite devices and components, radar and telemetry antennas, radar reflectors, range instrumentation, test equipment and special electronics equipment to customer specifications. **canoga**

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45
SMALL-SIGNAL GAIN-DB
25
10
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20

. . . another "first"*

A TRAVELING WAVE TUBE with 10 KMC BANDWIDTH

HUGGINS introduces the NEW HA-82

Available for delivery now is this Traveling Wave Tube which includes such features as an extremely wide frequency range . . . 10 to 20 KMC, with a minimum of 25 db small-signal gain and 1 MW saturation power output.
The HA-82 finds use in reconnaissance systems, Doppler simulator systems, as a driver for higher power tubes, etc.—many areas which previously required two or more tubes. This space, weight, and cost reduction, coupled with improved system reliability lend the HA-82 to airborne as well as fixed base applications.

*Other commercially available "firsts" from Huggins include:

- First forward wave amplifier in 1952
- First backward wave oscillator in 1954
- First PPM focused traveling wave tube in 1956
- First electrostatically focused TWT in 1958

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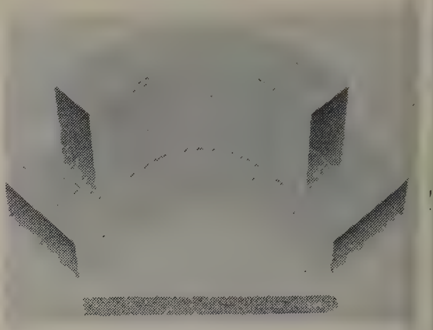
Openings exist in our expanding R&D program for Traveling Wave Tube and Microwave Vacuum Tube Engineers. Contact R.A. Huggins, 999 East Arques Avenue, Sunnyvale, California, REgent 6-9330

Industry News

(*Continued from page 75*)

INTASPACE CORP. EXPANDS FACILITIES



New equipment of advanced design for bending and forming rigid S-band waveguides has been placed into operation by Intaspace Corp., Bloomfield, N. J.

Heavier and more rigid construction makes possible the bending and forming of both aluminum and brass 1½ x 3 inch rectangular tubing to closer tolerance and greater accuracy.

This latest expansion now affords Intaspace Corp. customers a reliable source for close tolerance forming in all waveguide sizes from RG-99/U through RG-48/U and — 75/U.

— *m w j* —

GEORGE JOINS LFE SYSTEMS MARKETING DIVISION

George F. George has been named Northeast Regional manager for the Systems Marketing Division of Laboratory For Electronics, Inc., Boston, Mass. He had been marketing manager for the New England region prior to his promotion to the new post.

In the new capacity, Mr. George will be responsible for all Systems Division marketing efforts in the area and will continue to provide assistance to other divisions as required.

As vice president of the Wayne-George Corp. before joining LFE, Mr. George was responsible for military sales and contract administration. He had previously been manager of military marketing for the Electronics Corp. of America.

Recipient of a BS in mechanical engineering from Worcester Polytechnic Institute, he served as an aircraft engineering officer and test pilot with the U. S. Air Force during World War II.

— *m w j* —

LIONEL CORP. ACQUIRES TELERAD MANUFACTURING CO.

The signing of the contract by which The Lionel Corp., Irvington, N. J., acquired Telerad Manufacturing Company, New York City and Flemington, N. J., has been announced by General John B. Medaris, Lionel president.

Telerad is engaged in the development, production and sale of electronic devices and radar components. Its 1960 sales volume exceeds $2,000,000 and, according to General Medaris, its net earnings are expected to increase earnings per share of Lionel stock for the current year.

(*Continued on page 78*)

Circle Reader Service Card 37

THE MEASUREMENT OF TIME JITTER

by R. G. HEATON
Senior Engineer, Instrumentation Section
LABORATORY FOR ELECTRONICS, INC.

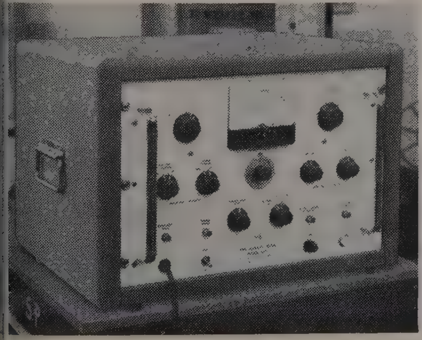
Pulse-time jitter is variation in the time spacing of pulse edges which results from modulation of some form, either cyclic or non-cyclic. Since timing or synchronizing is an essential process in many electronic devices, time-stability problems occur also. And in very sophisticated equipment, the specifications limiting residual time jitter become severe.

Time jitter is a common problem in the design of moving-target-indication (MTI) radars where undesired time modulation may cause fixed target pulses to appear as moving targets, thus causing the loss of ability to distinguish between the two target types. Time jitter may also limit the resolution of ranging circuits in fire-control radar systems. In pulse-communications systems, the noise level may be set by undesired time jitter resulting from noise or hum modulation.

Time jitter often turns up in unexpected places, hence the need to determine early in a design effort whether it exists and from what cause. For example, a tuning-fork oscillator was once selected as the pulse-repetition-frequency source for a high-performance MTI system on the assumption that the high Q of the fork would provide an extra measure of time stability. However, initial checks by means of a pulse-jitter tester revealed a completely unexpected peak jitter of 0.5 microsecond. The cause: extreme sensitivity to vibration and magnetic fields. The substitution of a simple Hartley oscillator reduced the jitter level below 0.005 microseconds, an improvement of 100:1.

Common causes of cyclic time jitter include hum and ripple modulation from heater and plate voltage supplies, and magnetic field pickup. Cyclic time jitter can be reduced as well as increased as a pulse proceeds through several stages, depending upon the relative phases of the modulation sources; but an increase is the usual case. Common causes of non-cyclic time jitter are noise and microphonic sensitivity to vibration.

Amplitude modulation of a pulse at some point in a circuit frequently leads to time modulation in a later stage of the circuit, and the ability to detect such modulation is helpful in the fault location process. The instrument to be described has this ability.



The measurement of time always implies a reference, and the practical problem of jitter measurement leads to definitions of three types of time jitter which correspond to three different sources of a time reference. The three types are:

1. *Pulse-width jitter* — the leading edge of the pulse is the reference for measurement of jitter of the trailing edge of the pulse. Both pulse edges are obtained from the pulse source under test by a single coaxial cable connection.
2. *Relative jitter* — the leading edge of a pulse from a second source is the reference for measurement of jitter of the leading edge of the pulse from the first source, such as the leading edges of a generated pulse and its trigger. Thus, two connections to the two pulse sources must be made.
3. *PRF jitter* — the time jitter of the leading edges of the pulses in a train relative to the leading edges of pulses in a second train having the same frequency and average phase, but highly stable for intervals of approximately one second. In the instrument described, the second pulse train is obtained from an internal stable oscillator which is phase locked to the first pulse train by a control circuit with a one-second time constant. In this case there is but one connection to the external pulse source being checked.

To be thoroughly useful and practical, an instrument to measure the time jitter of pulse edges (commonly called a pulse-jitter tester) must perform the following functions:

1. Linearly convert time variations to voltage variations.
2. Provide meter reading of peak jitter level.
3. Provide output for scope display of disturbance waveform.
4. Measure all three types of time jitter over a wide range of time-jitter amplitude.
5. Accommodate a wide range of pulse-repetition frequencies and input-pulse widths.
6. Accommodate both small and large time spacings between the reference pulse edge and the pulse edge under measurement.
7. Provide broadband amplification of pulses prior to conversion of time-variation information to voltage-variation information, in order to avoid attenuation of time-jitter information by filter action.
8. Maintain high signal-to-noise ratio by minimizing residual hum and noise pick-up in the instrument.

The LFE Model 5015 Time Stability Tester meets all of the above requirements in an easy-to-use instrument with stable characteristics. Accommodating pulse-repetition rates from 50 to 50,000 pps, it measures time jitters up to one microsecond peak with residual jitter (the equivalent of internal noise) below .0005 microseconds. Meter ranges are 3, 10, 30, 100, 300, and 1000 milli-microseconds peak. The time spacing between the reference pulse edge and the pulse edge under measurement can range from zero to thousands of microseconds, the upper limit depending on the pulse repetition frequency.

Amplitude jitter in a pulse train is detectable by varying the voltage level on the pulse at which the time jitter measurement is made. An important feature of the Model 5015 is that a front panel control is provided for this purpose. The instrument is also capable of measuring anode delay time, and slow changes thereof, a special application in the testing of hydrogen thyratrons.

Another unusual capability of this instrument is its ability to measure PRF jitter of a sine-wave as well as pulse-train input, provided that the slope of the sine-wave at the zero crossing is equal to or greater than approximately .06 volts/microsecond. Hence instability of a PRF pulse train can be traced back to its sine-wave source, if it has such a source.

Since a jitter measurement of a sine-wave input is possible, the relation between peak frequency deviation and peak time deviation may also be of interest. In the case where the time modulation of the input signal is sinusoidal and the input signal frequency is at least ten times the modulation frequency, the relationship is:

$$f_p = 2\pi f_d \, f_r \, \triangle t$$

where f_p = peak deviation frequency,
f_d = disturbance or modulation frequency,
f_r = PRF or sine-wave input, frequency, and
$\triangle t$ = peak time jitter or deviation.

Although the principal specifications of the Model 5015 are covered above, an interested reader can obtain more detailed information including mechanical and other data by requesting Bulletin 5015. For this bulletin, or the answers to particular questions, write Mr. Perry Pollins at the address below.

LABORATORY FOR ELECTRONICS, INC.
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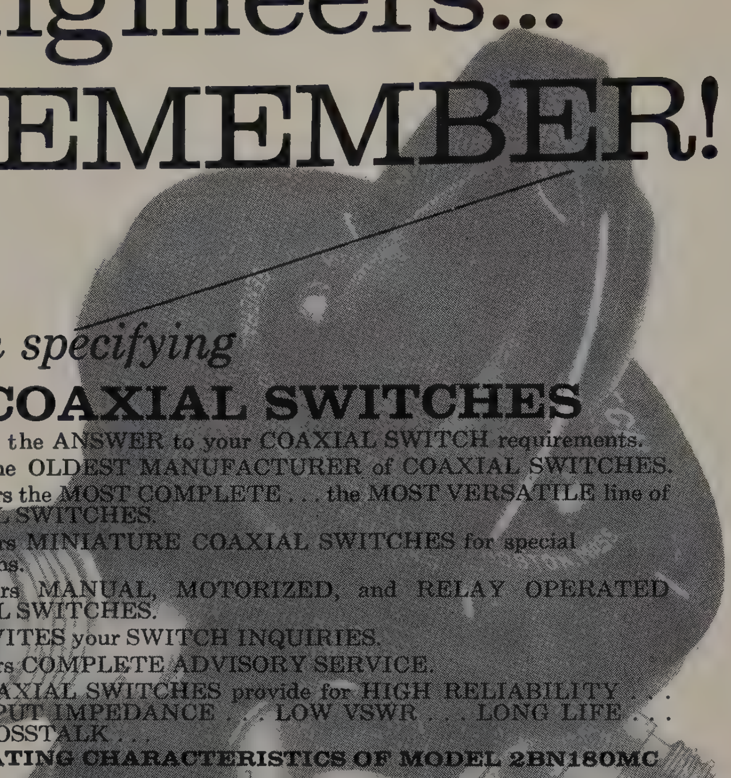

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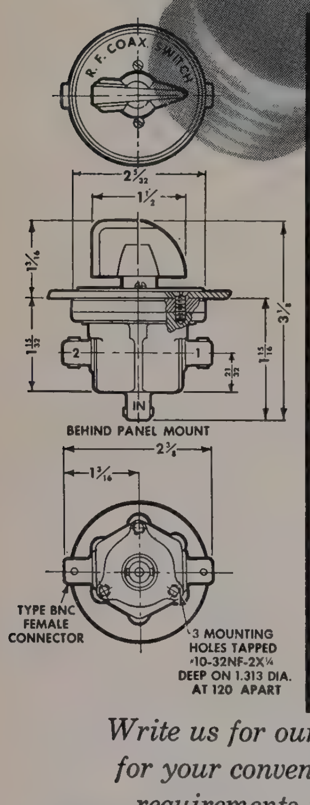
GCC COAXIAL SWITCHES provide for HIGH RELIABILITY . . . LOW INPUT IMPEDANCE . . . LOW VSWR . . . LONG LIFE . . . LOW CROSSTALK . . .

OPERATING CHARACTERISTICS OF MODEL 2BN180MC



R. F. COAX. SWITCH
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IN
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2¾
TYPE BNC FEMALE CONNECTOR
3 MOUNTING HOLES TAPPED #10-32NF-2X¼ DEEP ON 1.313 DIA. AT 120 APART

1. **Frequency Range** 0 to 10,500 Megacycles
2. **R. F. Characteristic Impedance** 51.0 Ohms
3. **Voltage Standing Wave Ratio** . . . . 1.2:1 at 3,000 Megacycles
4. **Insertion Loss** 0.3 DB at 3,000 Megacycles
5. **Crosstalk (Interchannel Attenuation)** . . . . 60 DB below operating level at 3,000 Megacycles
6. **R.F. Voltage Rating** 500 volts peak
7. **R.F. Power Rating** . . . . 100 Watt Avg. at 3,000 Megacycles
8. **Operative Life** 10,000 Cycles minimum
9. **Insulation Resistance** . . . . Greater than 500 megohms at 500 V.D.C.
10. **R.F. Connector** . . . . Type BNC (50 ohm) equivalent of UG-291/U
11. **Connecting R.F. Cables** . . . . 50 ohm coaxial cables with type BNC connector
12. **Rotor** Non-shorting
13. **Circuit** Single pole −2 position at 180°
14. **Operating Temperature Range** . . . . −55° to +55° centigrade
15. **Weight** 14 ounces

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RADAR TEST SETS, RADAR BEACONS, SIGNAL GENERATORS, AND PRIMARY STANDARDS FOR FREQUENCY, VOLTAGE AND PULSE POWER CALIBRATION

Industry News

(*Continued from page 76*)

General Medaris stated that the acquisition of Telerad is a second step in the program designed to enhance the position of Lionel in the electronics, missile and research and development field.

In September, Lionel shareholders approved the acquisition of Anton Electronic Laboratories, Inc., Brooklyn, N. Y., and Intercontinental Manufacturing Co., Garland, Texas, which are engaged primarily in electronics, nucleonics and missile production and research.

General Medaris said that Telerad, which was purchased with Lionel authorized, but unissued, common stock, will become a division of Lionel, and that its operations will continue to be under the direction of Charles George, who has agreed to remain with Lionel as Telerad President.

—*mwj*—

GE TO EXPAND COMMUNICATIONS PLANT

General Electric Company, Lynchburg, Va., will spend more than one million dollars in 1961 enlarging its Communication Products Department headquarters plant.

Built in 1957, the Lynchburg facility houses the firm's two-way radio, microwave-multiplex and power line carrier current businesses as well as some military communications lines.

The latest structural expansion will add over 100,000 square feet to factory, laboratory, office, cafeteria and service areas. A major portion will be used to increase manufacturing productive capacity.

Harrison Van Aken, the department's general manager, said the new wing provides for moderate future growth. It solves space problems caused by substantial increases in General Electric's two-way radio and fixed point microwave-multiplex communication businesses in the past two years, coupled with a continued up trend due in 1961.

—*mwj*—

TODD WILL DIRECT MILITARY PRODUCTS RESEARCH

Dr. Alva C. Todd, a specialist in electronic instrumentation, has joined The Hallicrafters Co., Chicago, Ill., as director of applied research for military products.

The announcement was made by William F. Frankart, director of engineering, who said Dr. Todd will head a group primarily responsible for developing military products with future market potential.

Holder of bachelor's, master's and doctor's degrees in electrical engineering from Purdue University, Dr. Todd was previously a staff member at the Illinois Institute of Technology's Armour Research Foundation. There his responsibilities included development of circular waveguide components and special-purpose microwave antennas.

He has also engaged in private engineering practice and served as consultant

(*Continued on page 80*)

Circle Reader Service Card 39

HUGHES LINE OF K_u-BAND BWO's

Hughes K_u-band backward-wave oscillators are all permanent-magnet tubes with the compact, lightweight Hughes design that has proved so reliable. They are ideally suited for use in microwave signal and sweep generators, panoramic receivers, spectrum analyzers, frequency scan and navigational radars and countermeasures equipment. They feature low spurious output and narrow spectrum width. They are designed to give you thousands of hours of trouble-free life.

The new 326H, shown here, is of particular interest. It is specifically designed for use in test equipment and other strictly commercial instrumentation—and priced for that market. It is a small, streamlined tube with excellent operating characteristics.

All the tubes shown here are production products. Hughes will ship to meet your immediate requirements. For prices and full particulars, write today to Hughes Microwave Tube Division, 11105 Anza Avenue, Los Angeles 45, California.

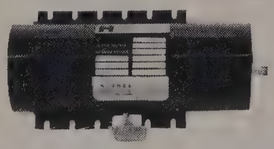
HUGHES
MICROWAVE TUBE DIVISION
MADE IN U.S.A.

THE 326H For commercial applications. Minimum output: 10 mw over 12.4 to 18 kmc band with power rising to 65 mw in the center of the band. Like all Hughes BWO's, the Hughes 326H requires no external cooling. All electrodes are isolated from each other and from the case.

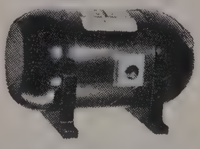
CREATING A NEW WORLD WITH ELECTRONICS

HUGHES

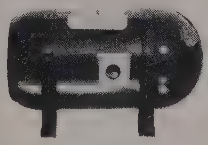
HUGHES AIRCRAFT COMPANY
MICROWAVE TUBE DIVISION



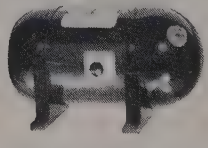
THE 315H Minimum average power: 50 mw. Frequency range: 15.8-17.2 kmc. Total weight of tube and magnet: 11.5 lbs.



THE 316H Full band. Minimum average power: 10-60 mw. Frequency range: 12.4-18.0 kmc. Total weight of tube and magnet: 11.5 lbs.



THE 317H Min. avg. power: 60 mw. Frequency range: 13.5-15.5 kmc. Total wt., tube and magnet: 10 lbs.

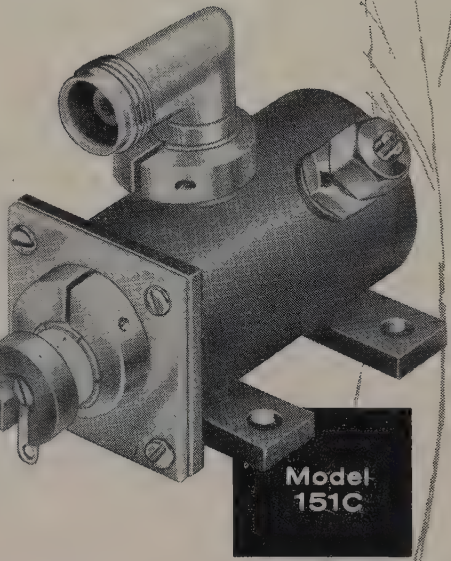


THE 318H Min. avg. power: 30 mw. Frequency range: 17.5-19.5 kmc. Total wt., tube and magnet: 10 lbs.

Circle Reader Service Card 40

MINIATURE
"C" BAND
TRIODE
OSCILLATOR

4½ ounces



60 Milliwatts at 4800 MC
20 Milliwatts at 6000 MC
±10 KC per degree C
±1 MC FM at 20 G's 20-2000 cps
Only 200V plate voltage

The John Gombos Co., Inc. Model 151C has applications as a local oscillator, CW signal source and driver for harmonic generators.

JOHN
GOMBOS
CO., INC.
WEBRO ROAD, CLIFTON, N. J.

We are a recognized, quality manufacturer of a complete line of Triode Oscillators, Amplifiers and Multipliers from "L" Band through "C" Band. We also produce a complete line of Tunable Band Pass Filters from "L" through "Ku" Band.

WRITE TODAY for Data Sheet C-2.

Industry News

(*Continued from page 78*)

to the microwave and radar departments at Farnsworth Electronics Company, Fort Wayne, Ind.; as director of engineering at Fournier Institute of Technology, Lemont, Ill.; and as a member of the electrical engineering staff at Purdue.

A native of Ligonier, Ind., Dr. Todd served as lieutenant at the U. S. Coast Guard laboratory during World War II. He is currently a member of the American Institute of Electrical Engineers, chairman of the electronics committee of its Chicago chapter, a senior member of the IRE and a registered professional engineer in Indiana and Illinois.

—mwj—

TRAK ELECTRONICS REPORTS SALES, PERSONNEL CHANGES

Elton T. Barrett, president of Trak Electronics Company, division of CGS Laboratories, Inc., Wilton, Conn., has announced the resignation of Carl G. Sontheimer as a member of the board of directors and secretary of the corporation.

Roger White, president of Tucor, Inc., Norwalk, Conn., has been appointed to the board and Francis M. Ellis, partner of the law firm of Carter, Ledyard & Milburn, New York City, has been elected secretary of the corporation.

Mr. Barrett reported that both sales and profits for the 1960 fiscal year were less than the preceding year. Recent reorganization within the company is expected to result in increased sales and profits during the coming year. Sales during the 1960 fiscal year ending October 31 were $1,850,000. Substantial losses were incurred during the first half of the year, but profitable operations during the last half have resulted in a net profit for the year of $5000.

New developments now under way and a more aggressive sales effort are expected to produce at least a 25 per cent increase in sales and an increase in profits during the coming year. Stockholders will be asked to vote on changing the corporate name of CGS Laboratories, Inc., to Trak Electronics Company at the next annual meeting in January.

—mwj—

LENKURT ELECTRIC CREATES PROJECT GROUP

Lenkurt Electric, San Carlos, Cal., has created a new project group to spearhead a stepped-up microwave products development program.

Maurice H. Kebby, formerly commercial products chief engineer, has been named project manager of the new group. He has been succeeded as chief engineer by L. Bruce Johnson, who moves up from the position of equipment and components engineering manager.

Also assigned to the group as project leaders representing the company's three major functions were John Coffin, production engineering manager, Myron E. Ferguson, development project engineer and Robert F. White, product manager from the marketing group.

—mwj—

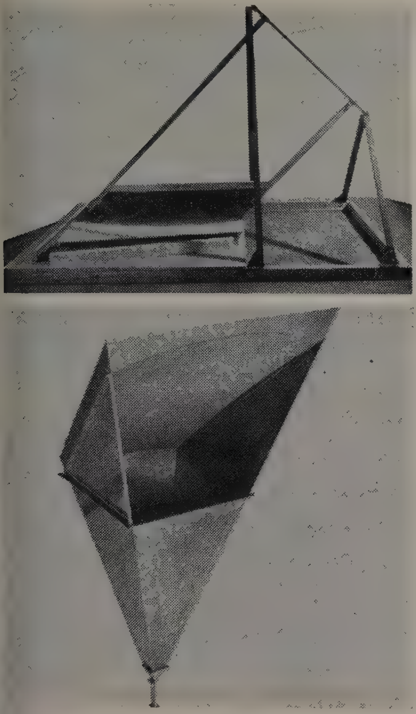
LETTERS TO THE EDITOR

Editor,
the microwave journal

Dear Mr. Saad:

We noted with interest the article by George R. Huard Jr. entitled "A Short Order Construction Technique for Test Antennas" in a recent copy of *the microwave journal.*

We have also used a similar technique to construct the paraboloidal surface of a scale model of a Horn Paraboloid Aerial. The model was about a quarter of full size and was constructed and tested at 8000 Mc/s to prove the design before making a full-size (2000 Mc/s) aerial, which was 27 feet high.



Top — Template, swinging about the axis of paraboloid, shapes the reflecting surface of a model horn-paraboloid aerial. Bottom — Completed six-foot high model horn-paraboloid aerial with copper-sprayed cement reflector.

The enclosed photographs show the swinging template used to form the surface while it was hardening and the completed model aerial.

Several materials were tested for use as the curved surface, and a mixture of cement with fine sand, reinforced with wire mesh, was found to be the most satisfactory, giving very little shrinkage. The reflecting surface was metallized with copper using a hot-spraying technique. The surface was not as smooth as could be obtained with plaster of Paris or similar materials, but was more than adequate and possessed a much greater strength than the other materials from which the metal surface tended to flake.

The entire model, apart from the metallizing, was made by laboratory staff, and the technique was found to be a quick and cheap method of constructing models of aerials.

F. J. Fisher,
E. M. Hickin
Research Laboratories,
The General Electric Company, Ltd.
Wembley, England

— m w j —

the microwave journal
Brookline 46, Massachusetts

Dear Sirs:

We are a group of students conducting a study on Microwaves with the aim of learning more about its business aspects and potential. We believe that a study of this kind can provide an immeasureable service to the Electronics industry.

The readers of *the microwave journal* could be of inestimable help to us by contributing some of their knowledge and opinions on this subject.

We urge them to write to us with such personal information or references to material which we might otherwise find difficult to locate. We have found this to be especially true on applications of Microwaves other than for communications.

We would appreciate replies being sent to the following address:

Microwaves
Doctoral Research
Graduate School of
Business Administration
Harvard University
Soldiers Field
Boston 63, Massachusetts

— m w j —

TO THE MICROWAVE PRODUCTS MANUFACTURER:

Your firm and its products will be confirmed in the forthcoming *microwave engineers' handbook and buyers' guide* if our industry questionnaire is completed and returned to us not later than March 1, 1961.

Write today if you have not received our questionnaire.

the microwave engineers' handbook
Horizon House, Inc.
1330 Beacon Street
Brookline 46, Massachusetts

MICROWAVE MECHANICAL GOMBOS ELECTRO-MECHANICAL ELECTRONIC SYSTEMS

MICROWAVE
MICROWAVE
MICROWAVE
CAVITIES
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MICROWAVE
COMPONENTS
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SUB-SYSTEMS
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MICROWAVE

WRITE TODAY for literature on the John Gombos Co., Inc. line of Triode Oscillators and Amplifiers, Tunable Band Pass Filters and Front End Assemblies. We would also appreciate receiving your special requirements for active and passive Cavities, Components and Sub-systems.

JOHN
GOMBOS
CO., INC.

WEBRO ROAD, CLIFTON, N. J.

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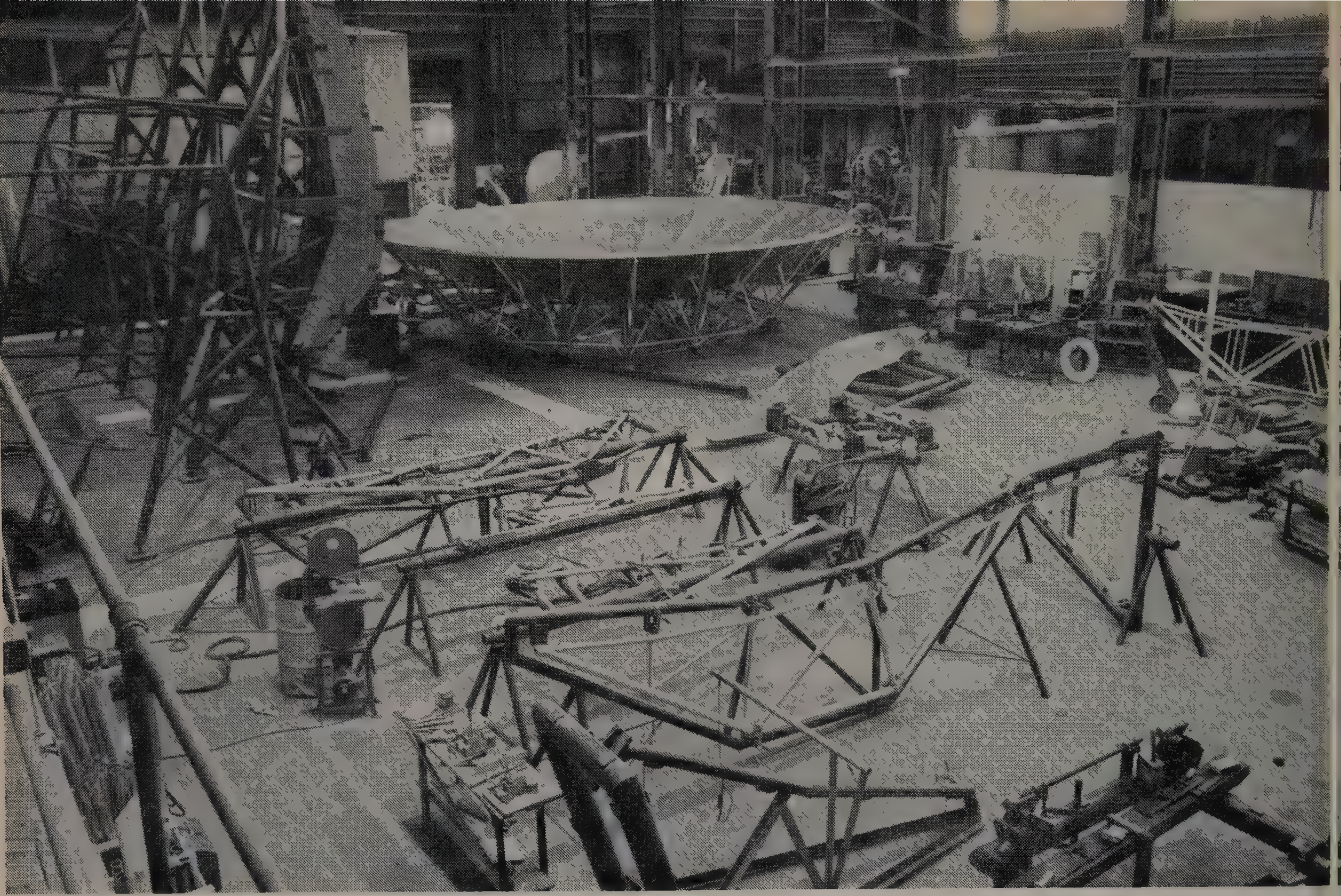


Interior view of ASI plant showing a 30-foot dish and a master mold under construction.

INTRODUCING

ANTENNA SYSTEMS, INC.

Hingham, Massachusetts

In an era of fast-moving developments, particularly in the microwave industry, the story of the establishment and growth of Antenna Systems, Inc. is one of the most interesting. In a period of less than twelve months a new organization which consisted of 14 stockholder-employees in January of 1960 has grown to become a major supplier for the users of microwave antennas.

"From the very beginning our objective has been to provide a complete line of products and service for antenna systems used in radar, tropospheric scatter, tracking and microwave communications," says President Charles W. Creaser, Jr. In working toward this goal, the company has rapidly added personnel and products which enable it to offer complete antenna systems.

History

ASI opened its doors for business on January 4, 1960, with 12,000 square feet of leased space in the Hingham Industrial Center, Hingham, Mass., no contracts, and the money invested by the 14 founders. Mr. Creaser explains that they took advantage of this situation in designing and developing a line of proprietary components for use in tropospheric scatter. These developments were unhampered by any fixed design or fabrication procedures and it was therefore possible to incorporate many innovations and unusual features in these advanced products. Primary emphasis was placed on antennas up to 30 feet in diameter which the company was equipped to produce.

As new designs reached tooling and prototype production, the working force was gradually expanded and reached 42 by the end of March. "Unusual" was also the key word when ASI purchased Spinform Inc., North Attleboro, Mass. This acquisition, which was moved in its entirety to the Hingham Plant, added a capability for precision metal working, particularly in spinning parabolic antennas up to 12 feet in diameter . . . and ASI needed such a facility to make their fabrication facilities more complete. This acquisition gave ASI a unique position among antenna manufacturers in that they are currently the only major antenna supplier with a spinning facility.

By April the production of 30 foot antennas and the addition of the Spinform equipment made it necessary to expand into an additional 18,000 square feet of adjacent manufacturing area, ideally suited for large antenna fabrication with high ceilings and overhead cranes. Additional space was added in June when, in recognition of the importance of research in the complex, fast-moving antenna field, ASI opened a new engineering laboratory including modern laboratory equipment for the design of antennas and RF components, as well as engineering offices, conference rooms and a drafting room. Along with this new facility they established outside pattern ranges, equipped with automatic pattern recording instruments and a remote-controlled pedestal for the testing of antennas.

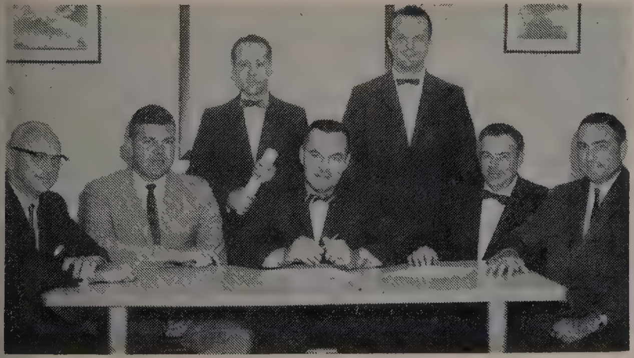
Personnel

The President of Antenna Systems, Charles W. Creaser, Jr., has been associated with the antenna field for almost twenty years. He has served as Project Manager and Sales Manager for several Greater Boston electronic and antenna companies. He joined D. S. Kennedy & Company in 1954 as Sales Manager and in 1957 was elected Vice President, in which position he was responsible for all phases of marketing including contract negotiations, engineering liaison with customers, advertising, field installation and service.

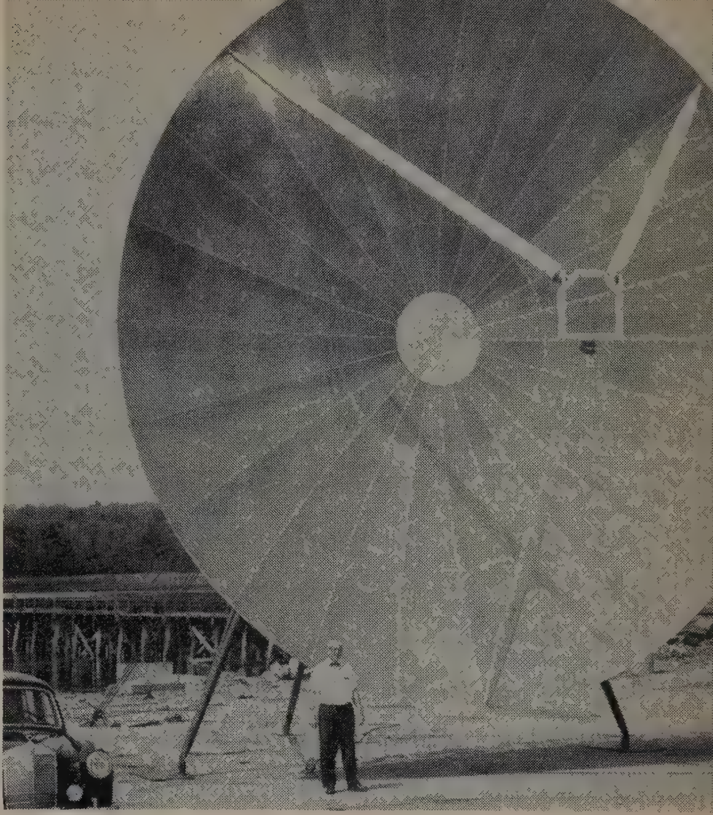
Walter W. VanderWolk, Jr., Executive Vice President, was Assistant to the President and Contracts Manager at Kennedy where his experience included contract administration, cost estimating, and direction of technical proposal work. Prior to this he served ten years in various engineering and administrative assignments as an officer in the Navy's Civil Engineer Corps.

Key department managers include Malcolm C. Winsor, Manager of Engineering, who has designed antennas ranging from 4 foot marine radar reflectors to the BMEWS antennas measuring 400 feet in length and 170 feet in height. His contributions to the advancement of antenna design techniques are widely recognized in the industry. Another is Albert K. Fowler, who joined ASI in March as Manager of Marketing. He was formerly Sales Manager of military products at Technical Appliance Corporation. A graduate of Rutgers University, he has had 10 years of experience in design, development and marketing of antennas.

Other officers are Leon O. Paulding, Treasurer, Merle C. Sherman, Financial Vice President, and Russell W. Leishman, Clerk and Manager of Administration. Milton F. Higgins, Production Manager, has had 35 years experience in pattern making and production of antennas, with particular emphasis on precision tooling. André M. Castellano has recently joined the company as Quality Control Manager, a position which he formerly held with Gabriel Electronics Division.



Management group at ASI consists of (left to right) Milton F. Higgins, production manager; Walter W. VanderWolk, Jr., executive vice president; Russell W. Leishman, manager of administration; Charles W. Creaser Jr., president; Malcolm C. Winsor, manager of engineering; Leon O. Paulding, treasurer; Merle C. Sherman, financial vice president.



ASI Model 103 — a 30 foot, solid surface antenna.

Antenna Systems' purpose is to provide the electronics industry with a specialized service to meet the rapidly changing needs for antennas. In doing this, the basic policy of ASI is to set the standards for the antenna industry through design innovations and recognition of customer requirements. The services offered include the design, manufacture and installation of reflectors, feeds, waveguide, rotary joints, towers, pedestals, and other related equipment for radar, space tracking, scatter and microwave communications.

In designing and building a precision 30 foot parabolic antenna as their first standard product, they set the standard by anticipating requirements which in most cases are still several years away. The 30 foot reflector features a solid surface for use at "X" and "K" band frequencies with surface accuracy that has previously been unavailable in production dishes of comparable size. About this Mr. Creaser says, "The use of higher and higher frequencies necessitates the need for more accurate antennas. We believed we could design and build a highly accurate production dish and were willing to risk our own money to prove this belief." The first production unit was carefully checked with a permanent swing template checking fixture to a static surface tolerance of .033 inch rms with a maximum deviation of .080 inch. This accuracy permits its use to frequencies above 10,000 mc/s and the structure is also rugged enough to withstand simultaneous loads of 4 inches of ice and winds of 150 mph. Custom units can now be furnished with approximately one-half the tolerance of the original unit.

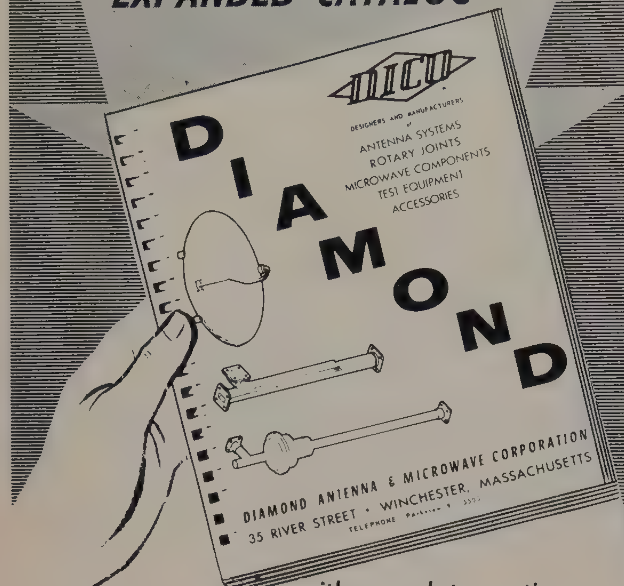
(*Continued on page 84*)

NEW . . .

from DICO

THE 1961 FULL-SIZE

EXPANDED CATALOG


DICO
DESIGNERS AND MANUFACTURERS of
ANTENNA SYSTEMS
ROTARY JOINTS
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DIAMOND ANTENNA & MICROWAVE CORPORATION
35 RIVER STREET • WINCHESTER, MASSACHUSETTS
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with complete sections on the latest advancements for

- **ANTENNA SYSTEMS**
- **WAVEGUIDE COMPONENTS**
- **COAXIAL COMPONENTS**
- **CUSTOM DESIGNS**

and the largest variety of

- **ROTARY JOINTS**

In addition, the new DICO catalog contains pictorial schematics with an appendix describing the new and modern DICO facilities. Included is an alphabetical index, assuring rapid locating of any component. A special section includes a questionnaire for your specific applications for immediate factory attention.

With Diamond's complete line of COMPONENTS and accessories, you are assured of the same reliability and accuracy that has made DICO nationally known as a pioneer with a long list of "firsts" in many fields. DICO's modern machine shop, laboratory and antenna test ranges offer the utmost in products, services and facilities. Whether you desire custom design work or standard components, our engineering and manufacturing facilities are at your disposal.

The new DICO catalog will be sent immediately upon receipt of your request written on your company letterhead, or by contacting our engineering representative in your area.

DIAMOND ANTENNA & MICROWAVE CORPORATION

River Street • Winchester, Mass.

ANTENNA SYSTEMS

(*Continued from page 83*)

The company has already produced other precision antennas varying in size from 12 inch diameter airborne radar reflectors to X-band scale models of giant antennas. They have also been able to spin 18 inch magnesium reflectors with tolerances of .020 inch.

ASI's major production achievement to date — the delivery of twelve 30 foot antennas for scatter communications in the record breaking time of 21 days from receipt of order — demonstrates their ability to act fast. This crash program required design and production, in addition to the antennas, of ground mounts, dual polarized feed horns, high power diplexers and other waveguide components, which have now become part of ASI's product line.

New designs recently completed include two types of 60 foot scatter antennas, both of which incorporate features which have hitherto not been used in this field. They are fabricated of galvanized steel and are designed for maximum interchangeability, standardization of parts, ease of erection and low manufacturing cost. A self-contained portable 30 foot antenna and trailer is the latest addition to ASI's products.

In addition to the diplexer, which is designed for easy tuning in the field, the waveguide component line includes bends, tuners, transitions, dummy leads and standard straight sections. These components of utilized fabrication methods were chosen to provide quality at the lowest possible cost.

Corporate Structure

The initial financing for ASI came from the original 14 employees. It is an employee-owned and employee-run concern, where employees are offered a plan that enables them to participate in the ownership of the firm. Although many offers for outright purchase or mergers have been refused, the rapid expansion of the company required outside capital, and in June a long term note was negotiated with Microwave Associates Inc. of Burlington, Mass. Under this arrangement Microwave Associates obtained rights to a maximum of 28 per cent of ASI common stock and the association of the two companies permits the pooling of technical research which allows each firm to draw on the talents of the other.

Now and the Future

Today, twelve months after its modest start, ASI employs 100 people whose combined experience and know-how in the design and building of antennas is difficult to match. With the high morale which results from employee ownership and with necessary financial backing to continue an orderly rate of growth, Antenna Systems, Inc. seems well on its way to realizing its goals.

With the necessary equipment, manpower and capital to handle almost any antenna problem, management is operating in accordance with detailed plans and targets which are projected in advance through 1965. Gross sales to date have exceeded original estimates. Sales for the first year were in excess of $1,000,000.

As space travel comes nearer and nearer to reality and the need for more and better communication systems grows, Antenna Systems hopes to provide a complete flexible, fast-moving antenna service and to work for new and improved antenna products.

PRD *previews/reviews/design notes*

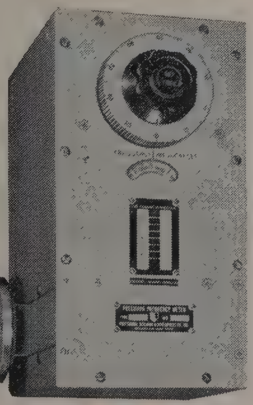
Measuring Microwave Frequencies

Of the four basic microwave measurements, i.e., (1) VSWR (2) Power (3) Attenuation and (4) Frequency, the latter is probably the easiest to determine. There are available, of course, many frequency meters with varying degrees of accuracy. These are generally either tunable cavity-type resonators or devices which utilize a harmonic of a low frequency standard.

Cavity Frequency Meters

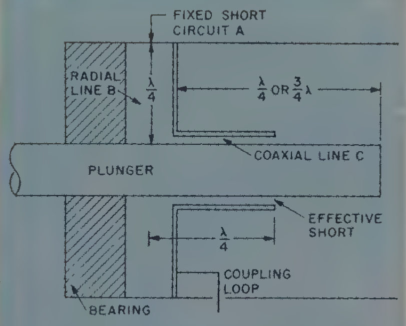
Cavity-type frequency meters, both coaxial and waveguide, make use of the absorption (reaction) or transmission properties of selectively tuned resonators. In use, the meter is inserted between the signal source and the r-f detector indicator. The reaction or absorption type instrument is tuned to obtain a decrease in power level at the detector and, consequently, is particularly useful as a search frequency meter. The transmission type unit passes only those frequencies within the pass band of the resonant cavity and so is most convenient for monitoring or filtering purposes.

Of the dozens of frequency meters available from PRD, among the most popular and simplest to use are the PRD 555-579 Series. They are high precision, direct reading, hermetically sealed, temperature compensated instruments and are particularly useful for laboratory and production line testing or as secondary standards.

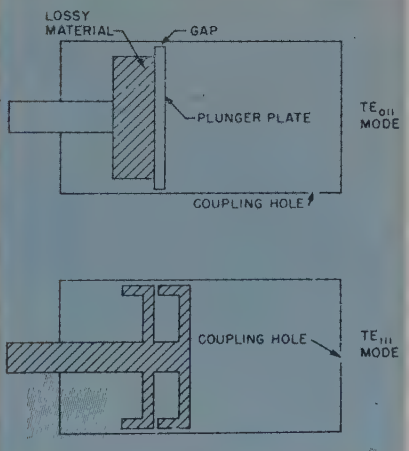

PRD 555

At X band frequencies the PRD 559-A or B, which are available in both reaction and transmission types, are accurate to 0.015% with readout directly in megacycles.

Typical cross sectional views are shown for both coaxial and waveguide resonating cavities in this series of precision meters.



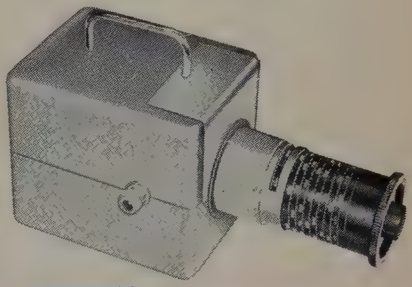
COAXIAL TYPE



WAVEGUIDE TYPE

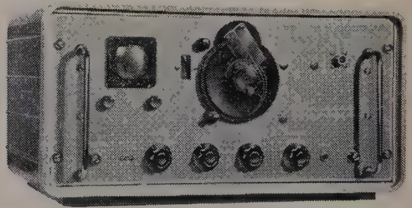
UHF Frequency Meter

Another popular and useful meter in the UHF television band is the PRD 587-A, which is accurate to ±0.2%. It can be used for alignment of tuned circuits and oscillators in the frequency range of 250 to 1000 megacycles. The direct reading dial has a scale length of 60 inches for easy and accurate readout. For convenience and protection the meter is housed in a metal carrying case with a handle.


PRD 587-A

Precision Heterodyne Frequency Meter

An instrument that uses the heterodyne principle with a crystal oscillator as its standard is the PRD 504 Precision Heterodyne Frequency Meter. It has an extended range of 100 to 10,000 megacycles and is accurate to 0.002%. This versatile and portable instrument is used for laboratory and field testing of transmitters, receivers, and signal generators. A cathode ray tube is provided for zero-beat indication on the front panel.


PRD 504

If you would like some assistance with your frequency measuring problems, please contact our Applications Engineering Department.

We have many interesting openings for engineers...contact Mr. John R. Zabka

PRD
ELECTRONICS, INC.
A Subsidiary of Harris-Intertype Corporation
Formerly Polytechnic Research & Development Co., Inc.

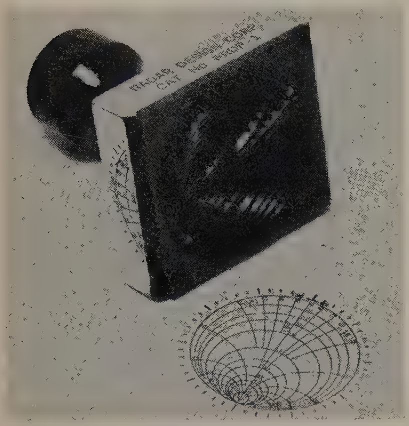
202 Tillary Street, Brooklyn 1, N. Y.
ULster 2-6800
1608 Centinela Ave., Inglewood, Cal.
ORegon 8-6922

HARRIS INTERTYPE CORPORATION

Circle Reader Service Card 44

New Products

SMITH CHART STAMP OFFERED BY RADAR DESIGN CORP.



A Microwave Impedance Chart Stamp for making a clear, scaled impression of the "Smith Chart" is available from Radar Design Corp., Syracuse, N. Y.

The rubber stamp, No. RRDP-1, designed primarily to stamp into notebooks for plotting recorded data, obviates pasting in the conventional 8½ x 11 inch paper chart.

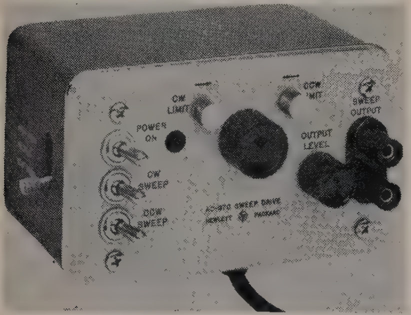
Other applications include illustrating technical reports, stamping scrap paper for "thinking" charts and replying graphically to technical memos concerning microwave impedance measurements.

Price is $9.50 each from stock.

Circle Reader Service Card 100

—mwj—

DRIVE SWEEPS OSCILLATORS THROUGH FREQUENCY RANGES



A new sweep drive which automatically sweeps oscillators and other tunable devices through their frequency ranges is now available from Hewlett-Packard Co., Palo Alto, Cal.

The new unit, Model AC-97C, is a motor accessory for Hewlett-Packard's Model 302A wave analyzer. In this application, it sweeps through the entire range of the wave analyzer for automatic plots of harmonics, spurious responses or intermodulation products with an X-Y recorder. It also converts the model 302A to a sweep oscillator-tuned voltmeter for automatic frequency response measurements, even in noisy systems.

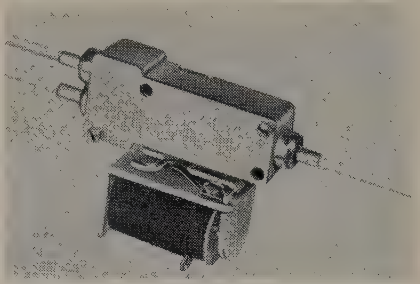
Model AC-97C has two sweep speeds and a neutral. The fast sweep covers the frequency spectrum rapidly while the slow sweep gives a high resolution plot. In neutral position the driven unit can be tuned manually. Sweeps can be reversed automatically when limits are reached, thereby providing a continuous sweep for oscilloscope presentations, or, for convenience in X-Y recordings, the sweep can be stopped automatically when the limit is reached.

Circle Reader Service Card 101

—mwj—

COAXIAL RELAYS ACCENT LOW CROSSTALK AND VSWR

Low crosstalk and standing wave ratio are featured in a new low-cost coaxial relay manufactured by Allied Control Co., Inc., New York, N. Y., for mobile and stationary radio transceiver, VHF, UHF and video studio switching. For antenna transfer the new SPDT coaxial relays are rated at 150 watts maximum up to 470 megacycles when inserted in a properly terminated 50-ohm line.



Crosstalk is 40 decibels minimum from zero to 470 megacycles; VSWR is less than 1.2, zero to 1,000 megacycles. Lower in cost than conventional coaxial relays of their rating, this new RB series can be supplied with any length coaxial leads in the RG58A/U and RG188/U cable sizes. They resist shock up to 30g operational and withstand vibration of 10 to 55 cps at 0.06 inch double amplitude.

Minimum weight is 3 ounces with the maximum determined by the cable type and length chosen. Coaxial cables are permanently secured internally to contact terminals. Three coil types are available — RB, 1 watt; RBA, 2 watts; and RBB, 2 watts nominal coil power operating at ambient temperatures up to plus 25°, 80°, and 125°C, respectively. Coil voltages for each type include 6, 12, 24/26.5, 48 and 115 volts dc. Coil resistances range from 47 to 18,900 ohms for the RB, and from 19 to 7250 ohms for the RBA and RBB types.

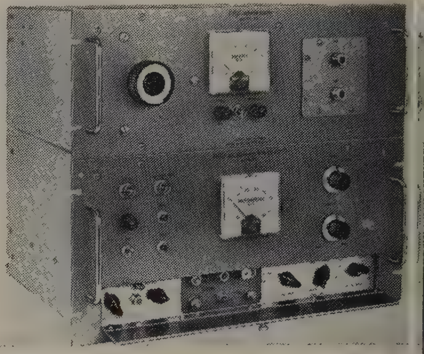
Circle Reader Service Card 102

—mwj—

ALFRED OFFERS LINE OF LOW NOISE AMPLIFIERS

A line of low and medium noise figure Microwave Amplifiers — covering 500 Mc to 18 kMc — is now available from Alfred Electronics, Palo Alto, Cal.

Alfred's 5000 Series amplifiers include standard bands such as 1 to 2 kMc, 2 to 4 kMc , 4 to 8 kMc, 7 to 11 kMc, 8 to 12.4 kMc and 12.4 to 18 kMc. These amplifiers provide 10 to 15 db noise figures with 25 db or more gain. Units are available which provide 7 db NF over lesser frequency ranges.



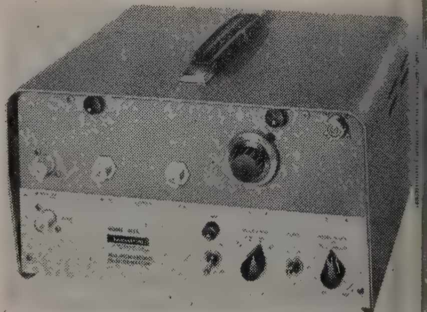
Each Microwave Amplifier consists of TW tube, power supply, and where required, a specially designed focusing solenoid with its power supply. Each power source has a wide adjustment range so that the Amplifier may easily be converted for use with new tube types as they become available. TWT can be direct coupled to front panel BNC connector for external AGC or AM modulation.

The TW tube is mounted either as an integral part of the Microwave Amplifie or may easily be removed and mounted remotely as preamplifier. For remote operation, extra heater and solenoid powe overcomes line losses and dc heater supply prevents inter-action.

Circle Reader Service Card 103

—mwj—

LUMATRON PRODUCES RISETIME PULSE GENERATOR

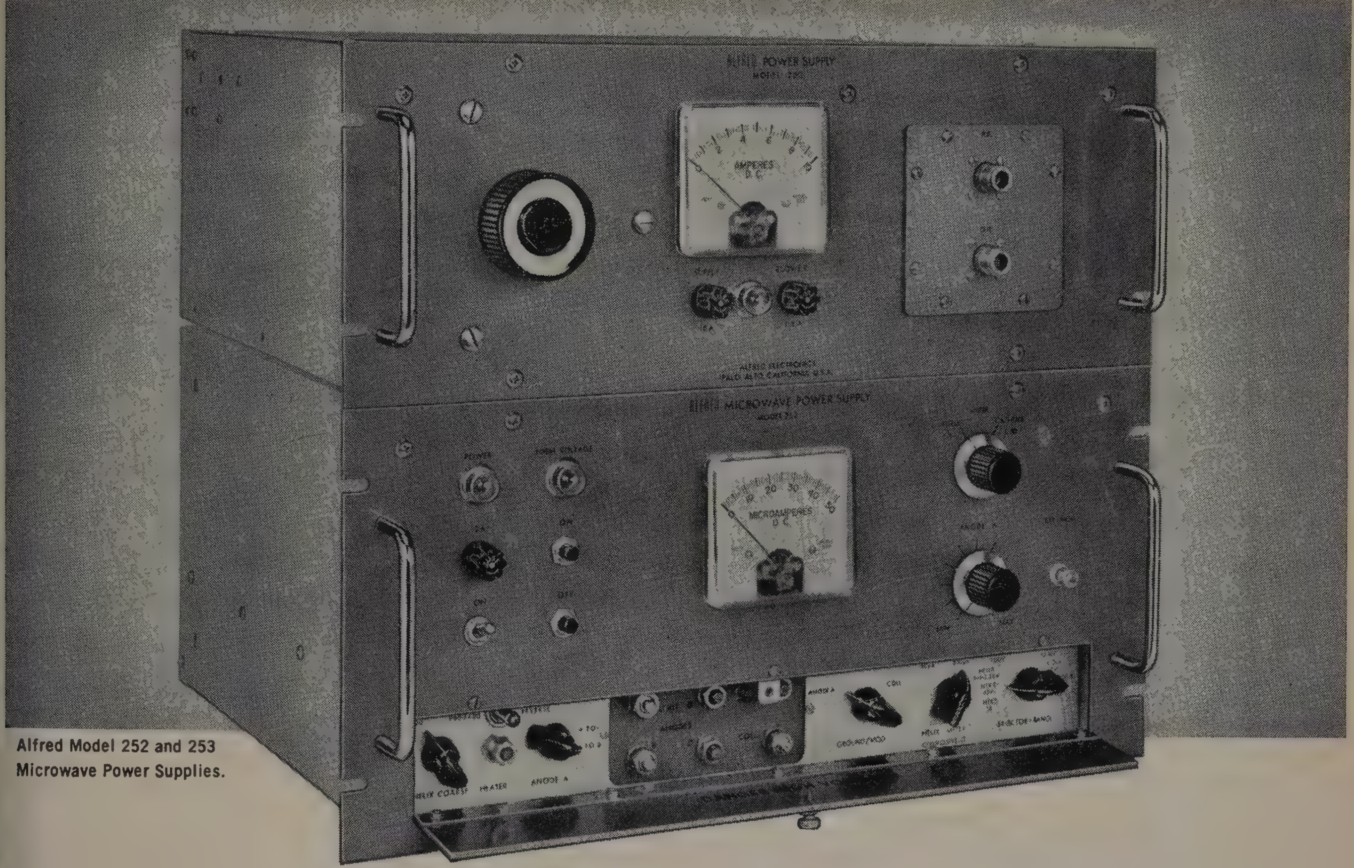


Model 303A Risetime Pulse Generato from Lumatron Electronics, Inc., New Hyde Park, N. Y., features risetimes o 0.3 ns, a minimum pulse width of 0.7 n and built-in calibrated widths of 5, 1 and 20 ns. Other pulse widths can b produced readily using external length of coaxial cable. The instrument also features calibrated amplitudes to ± 100 v into 50 ohms, adjustable leading edg damping and a separate trigger output.

Variable repetition rates from 20 to approximately 300 pps, make the Mode 303A suitable for display on samplin

(*Continued on page 88*)

Power low noise figure TW tubes



Alfred Model 252 and 253 Microwave Power Supplies.

with one ALFRED *supply!*

This compact ALFRED ELECTRONICS microwave power supply provides electrode voltages for nearly all medium and low noise figure TW tubes. Companion solenoid supplies for electromagnet focused TW tubes are available. Here are the major advantages of this precision ALFRED supply:

☆ FLEXIBILITY

One electrode supply operates most presently known tubes. It will operate new tubes as they become available. Cover present and future needs with *same* supply.

☆ INTERCHANGEABILITY

Build all your low noise amplifiers around standard unit. Simplify servicing. Stock parts for only one type of supply.

☆ LOCAL OR REMOTE OPERATION

Model 252 design permits remote operation of TW tube as may be required with broad-band preamplifiers. Heater supply has extra wide voltage range to compensate for cable IR drop.

☆ SIMPLE OPERATION

Only two controls on front panel for day-to-day operation. Set-up controls are on recessed subpanel. All voltages and currents are internally measured using front panel meter and recessed selector switch.

### ☆ STABILITY

Electrode supplies are well-regulated and designed for minimum drift. Use of dc heater power reduces spurious amplitude modulation.

☆ 50 TO 450 CPS INPUT

Wide band power input permits use with almost any available power source.

☆ ECONOMY

Separate solenoid supplies are available. Purchase only the supply you need when you need it.

KEY SPECIFICATIONS FOR MODEL 252
Helix: Voltage, 75 to 1400 v; Ripple, less than 20 mv pk-to-pk; Regulation, ±.03% line. **Collector:** 0 to +300 v relative to helix. Four Anodes, ranging from —100 v to +900 v relative to cathode. Heater, 0 to 11 v DC at 0 to 1 amp with 2% regulation. All electrode supplies internally metered.

Two low ripple Solenoid Supplies are available. Both are adjustable over a wide range providing adequate power for most TW tube focusing magnets. Model 253 is unregulated; Model 254 is current regulated.

KEY SPECIFICATIONS FOR MODEL 253
0 to 105 v DC at 0 to 7.5 amp or 0 to 110 v at 6 amp. Ripple, .5% pk-to-pk.

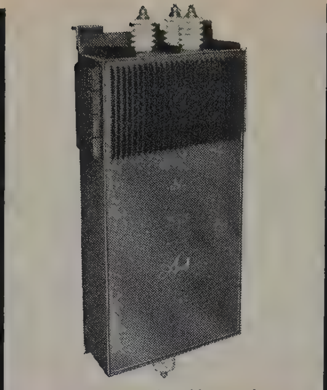
KEY SPECIFICATIONS FOR MODEL 254
0 to 100 v DC at 0 to 7.5 amp or 0 to 105 v at 6 amps. Ripple, .5% Regulation, ±1% for ±10% line change or 30% load change.

PRICES: Model 252, $890; Model 253, $200; Model 254, $350.

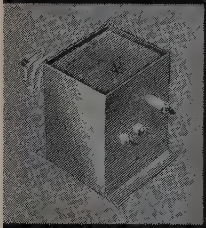
WRITE FOR MORE DATA—*Contact your* ALFRED *engineering representative for more details, or write us directly at Dept* 69.

ALFRED ELECTRONICS
897 Commercial Street • Palo Alto, California
DAvenport 6-6496

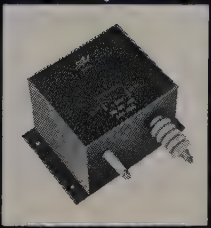
HIGH POWER MATCHED PULSE COMPONENTS



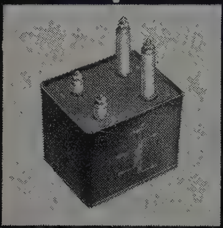
Pulse Forming Networks



Pulse Transformers



Charging Reactors



Oscillator Filament Transformers

FEATURES

- Stable performance at High Temperatures
- Widest Range and combination of Electrical parameters
- Oil filled units hermetically sealed in welded seam cases
- Designed to meet exact system requirements
- Meets and exceeds all Mil requirements

Axel Pulse components are designed for use in Industrial, Military and Research application where electronic equipments demand a specific energy impulse of accurate shape and duration. All Axel Pulse Components have a high reliability and are designed to meet minimum space and weight requirements.

Axel

AXEL ELECTRONICS, INC.
134-20 Jamaica Ave., Jamaica 18, N. Y.

High Voltage Capacitors, Pulse Magnetic Components, Pulse Networks, Pulse Packages, R.F. Suppression Filters.

New Products

(*Continued from page 86*)

oscilloscopes. In addition, the fixed repetition rates of line and 2 times line frequency simplify power line hum detection in circuit testing.

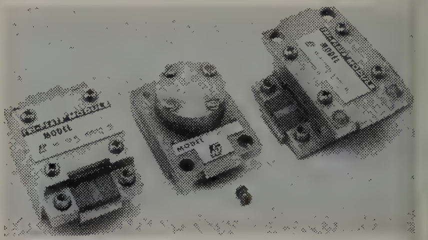
Model 303A employs a new coaxially mounted, high speed mercury wetted switch with an adjustable damping vane for easy undershoot and overshoot adjustments. The mercury capsule can be easily removed for replacement or the entire cavity assembly can be supplied as a unit for safe, rapid replacement.

Model 303A is specially designed for operation in today's ultra fast pulse applications.

Circle Reader Service Card 104

— m w j —

SANDERS PRODUCES MODULE SEMICONDUCTOR MOUNTS



Sanders Associates, Inc., Nashua, N. H., announces several new Tri-Plate® Module semiconductor mounts. Designed for use with pill tunnel diode and pill varactor packages similar to those used by Microwave Associates and Sylvania, these new mounts are complete electrical and mechanical subassemblies. The standard 50-ohm impedance model is available for immediate shipment while special impedances from 5-100 ohms are shipped within 4 weeks after the order is received.

The new semiconductor mounts for use with 1/8 inch diameter, 1/8 inch long pill packages are the latest addition to the continuously growing Tri-Plate Module semiconductor mount line.

Tri-Plate Module mounts are available in 1, 2, 3 and 4 port series and shunt connected diode models, with or without RF bypass. Series connected mounts are also available with either or both ground returns and bias injection. The shunt connected mounts can be supplied with bias injection terminals which are not considered ports. Two port transistor mounts are available with grounded emitter, grounded base, or 3 port mounts with emitter, base, and collector terminals connected to RF ports.

Circle Reader Service Card 105

— m w j —

ULTRA LOW-NOISE TW AMPLIFIER OFFERED BY WATKINS-JOHNSON

Watkins-Johnson Co., Palo Alto, Cal., has announced a full octave band ultra low-noise traveling-wave amplifier.

The WJ-212 covers the 1-2 kMc band with spot noise figures below 3 db and fixed voltage noise figures below 5 db across the band.

(*Continued on page 92*)

Circle Reader Service Card 46

ANOTHER FIRST FOR THE INDUSTRY

from the publishers of *the microwave journal*

the microwave engineers' handbook and buyers' guide

Since its original concept in 1958, the microwave journal has devoted itself to the principle of **saving the engineers' time.**

Continuing in this principle, we offer a supplementary volume — **the microwave engineers' handbook and buyers' guide** — which will appear about September 15, 1961.

Now for the first time there will be available to the microwave industry, in one volume, first, a comprehensive handbook, providing a single source of up-to-date microwave engineering reference material, and second, a buyers' guide, cataloguing microwave industry activities, and detailing the various functions of the entire microwave field.

Typical of the valuable engineering data included in the handbook are the complete Sperry tables of standard rectangular waveguide constants as a function of frequency, and the Bell Laboratory table of the first 700 zeroes of Bessel functions for use in circular waveguide and cavity design problems.

USE THIS HANDY POST CARD FOR FURTHER INFORMATION ON MICROWAVE ENGINEERS' HANDBOOK AND BUYERS' GUIDE.

the microwave engineers' handbook and buyers' guide

Offers to the microwave industry an unparalleled marketing opportunity.

It features:

- A product directory, covering over 100 categories of microwave products.
- A manufacturers and sales representatives directory.
- An extensive advertising and catalog section.

What is an advertisement worth? It is only as good as the medium it uses to reach its natural market. **The buyers' guide section of the handbook will be placed, free, into the hands of the largest concentrated group of microwave product specifying engineers in the world.**

All qualified recipients of *the microwave journal* are eligible to receive **the microwave engineers' handbook and buyers' guide.**

the microwave journal

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Northeast

Emile H. Hajar
1330 Beacon Street
Brookline 46, Massachusetts
REgent 4-3220
Direct Dial Code: 617

Mid-Atlantic

A. F. Dolbey
1330 Beacon Street
Brookline 46, Massachusetts
REgent 4-3220
Direct Dial Code: 617

Midwest

The Farley Company
120 South LaSalle Street
Chicago 3, Illinois
FInancial 6-3074
Direct Dial Code: 312

West Coast

Dillenbeck-Galavan, Inc.
266 South Alexandria Avenue
Los Angeles 4, California
DUnkirk 5-3991
Direct Dial Code: 213

CALL OUR REPRESENTATIVE IN YOUR AREA OR MAIL THIS HANDY POST CARD.

How Indiana Steel's engineers help you solve micro-wave magnetic problems

Engineers at The Indiana Steel Products Company are in constant contact with leading manufacturers of micro-wave equipment on problems involving permanent magnets. Consultations with Indiana's magnet specialists have resulted in time and cost savings — often eliminating expensive redesign.

CASE IN POINT:

A leading micro-wave component manufacturer. *Problem:* Produce a special load isolator magnet to fit smaller space contour in a new radar unit. Also, deliver the new magnet to the customer in 12 days.

Solution: Indiana engineers turned to their previous design files, selected an existing magnet and modified it to meet the new size specifications. Gauss tests showed that the new design met the customer's specified magnetic field range. The magnet was delivered within the time specified.

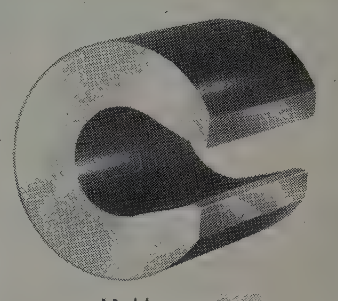
This is just one of many hundreds of cases where Indiana permanent magnet specialists have applied their unequaled experience to solve a magnet problem *ahead* of a customer's deadline. Indiana not only has the engineering know-how, but also manufacturing equipment from previously designed magnets which may be quickly adapted to meet special requirements.

THREE BASIC DESIGNS FOR LOAD ISOLATOR APPLICATIONS

Permanent magnet specialists at Indiana Steel utilize three basic magnet designs for load isolator applications. These are, two variations of the C magnet, and the U magnet. All three of these designs can be varied to meet specific customer requirements. Actual size and shape of any individual magnet is dependent upon size limitation of the load isolator, and the magnetic field strength needed.

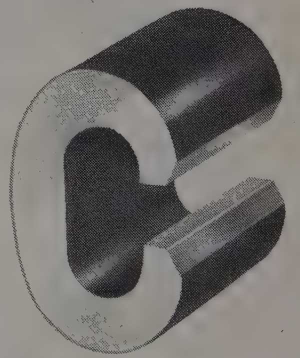
WIDE EXPERIENCE IN MICRO-WAVE APPLICATIONS

Magnet specialists at Indiana have designed and produced permanent magnets for a wide range of micro-wave applications including pm-focus traveling wave tubes, load isolators, radar magnetrons, backward wave oscillators. And, you can be sure the material selected is *best* for your particular application because Indiana Steel produces *all* permanent magnet materials. Our engineers will give prompt attention to your micro-wave problems or any other permanent magnet applications. Call your Indiana man or write us direct. Ask for Catalog No. 20, "Alnico V Load Isolator Magnets." Dept. Q-2



U Magnet

C Magnet



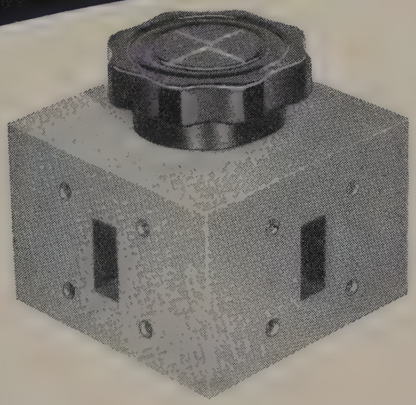
Flat C Magnet

DIVISION OF
INDIANA
GENERAL
CORPORATION

INDIANA STEEL PRODUCTS
VALPARAISO, INDIANA
In Canada: The Indiana Steel Products Co. of Canada Limited, Kitchener, Ontario
INDIANA PERMANENT MAGNETS

Circle Reader Service Card 47

Waveguide Switches



Waveline precision Waveguide Switches are available in seven waveguide sizes to cover the frequency range of 3.95 to 40.0 KMC. These manually operated devices have been designed for applications in the laboratory or for microwave systems to make alternate connections between two waveguide inputs and two waveguide outputs.

Excellent electrical characteristics are achieved by unique precision and assembly techniques which Waveline has developed to provide the highest quality of microwave instruments. Full waveguide range operation is obtained with a VSWR of 1.10 maximum and an isolation greater than 60 db.

The switches are normally supplied with rotation in the narrow wall plane (circular bend of the rotor in the "E" plane) and are manually operated by means of a knob. Also available are "H" plane versions which are designated by suffix letter H.

Waveline Model No.	Frequency Range, KMC	Waveguide Type
378-E	3.95 to 5.85	RG-95/U
478-E	5.85 to 8.20	RG-106/U
578-E	7.05 to 10.00	RG-68/U
678-E	8.20 to 12.40	RG-67/U
778-E	12.40 to 18.00	RG-107/U (AL)
878-E	18.00 to 26.50	RG-66/U (AL)
1078-E	26.50 to 40.00	RG-96/U (AL)

WAVELINE INC.
CALDWELL, NEW JERSEY
Phone: CApital 6-9100 TWX Caldwell, N. J. 703

Circle Reader Service Card 48

New Products

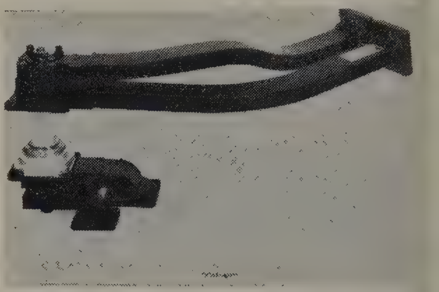
(*Continued from page 88*)

Externally, the new tube is compatible in size, weight and power supply requirements with present solenoid-focused low-noise tubes, so that "retro-fitting" changes are minimized. Long life is anticipated because of the low cathode operating temperatures (typical 650° C) and excellent tube vacuum. Tubes are priced at $2950, with four to eight weeks delivery.

Circle Reader Service Card 106

—mwj—

ROTARY JOINT'S TWO CHANNELS PROPAGATE X-BAND ENERGY



A dual channel microwave rotary joint, model RJXD-1C, both channels of which propagate X-band energy, is available from Canoga Corp., Van Nuys, Cal. It consists of sections of waveguide, waveguide to coaxial transitions and a coaxial non-contacting choke joint. The entire joint employs ball bearings and is sealed for pressurization.

The high power channel operates in a frequency range of 8.5 to 9.6 Gc; power handling of 250 kilowatts; VSWR 1.2; Insertion loss 0.4; VSWR WOW .04 db; flanges UG-137A/U.

Circle Reader Service Card 107

—mwj—

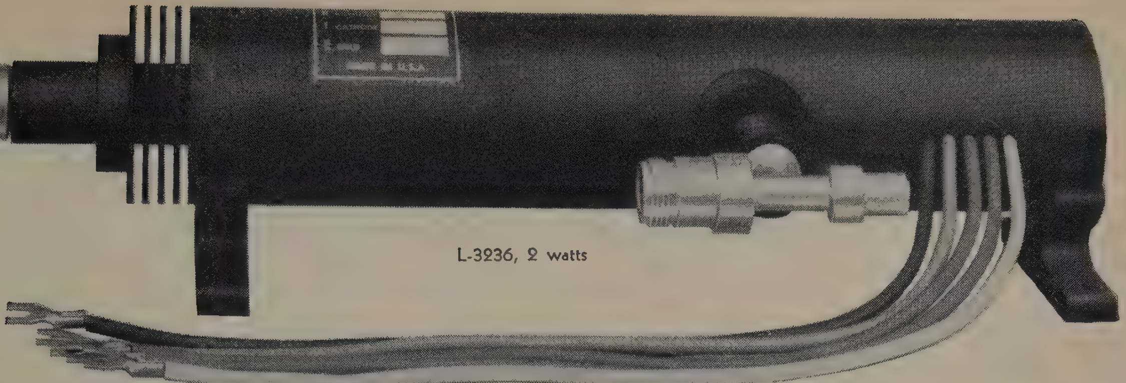
PUREGAS POLE MOUNTED AIR DRYER AVAILABLE FOR MICROWAVE FIELD

Puregas Equipment Corp., Copiague, N. Y., has announced extended development of its pole mounted air dryer for applications in constant flow pressure systems, such as those utilizing microwave equipment.

The Puregas Model 600 Pole Mounted Air Dryer is designed to deliver 600 standard cubic feet of dry air per day at adjustable pressures from 0 to 15 psig, and operates within an ambient temperature range of —40°F to 120°F. Complete with air compressor, motor, heat exchanger refrigeration system and alarm facilities, all encased in a durable aluminum cabinet, the unit is fully automatic.

Air drying is accomplished by combining compression, refrigeration and chemical absorption. In operation, ambient air is compressed several atmospheres, then cooled in a refrigerated heat exchanger to subzero temperatures. This squeeze-freeze effect condenses most of the moisture content out of the air stream. Residual entrained moisture is then removed in a small reserve tower of desiccant before

(*Continued on page 94*)



L-3236, 2 watts

TWTWINS

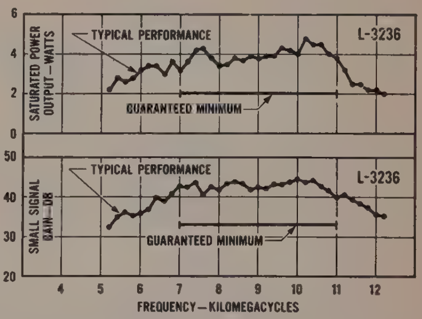
L-3266, 20 milliwatts

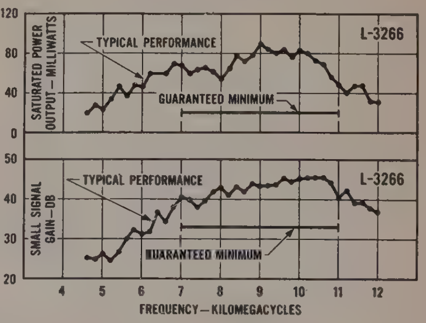
These Litton TWT twins are PPM focussed X-band traveling wave tubes. They are *not* prototypes. They are metal and ceramic tubes in field application *now*.

Designed to cover X-band with minimum saturated CW power of 20 milliwatts (L-3266) and 2 watts (L-3236), they may be operated in cascade to amplify signals as small as —50 dbm to the 2 watt level. Their performance, far exceeding the conservative specifications, is evident in the accompanying graphs.

Small size (less than 12″ in length), light weight (under 4 pounds each), and extreme environmental capability (temperature compensated —54°C to 86°C) make these tubes the ideal choice for military applications. A typical airborne equipment, designed and manufactured by Granger Associates of Palo Alto, California, incorporates the L-3266 and L-3236 and occupies only 0.75 cubic feet, including all necessary power supplies, modulating circuitry, cooling, etc. This equipment is now in field operation.

If your work involves ECM repeaters, radar target enhancement, frequency diversity radar or any application requiring broadband microwave amplifiers, appraise these new tubes. In production quantities their price is the lowest in the field. Ask for catalog sheets on the L-3266 and L-3236. Address: Litton Industries Electron Tube Division, 960 Industrial Road, San Carlos, California.





LITTON INDUSTRIES
Electron Tube Division
MICROWAVE TUBES AND DISPLAY DEVICES

"Capability that can change your planning"

Circle Reader Service Card 49

COAXIAL
BROAD
BAND
FERRITE
ISOLATORS

IN SIZES FOR EVERY APPLICATION

Now—from Kearfott, a new and broader line of Ferrite Isolators to satisfy the most exacting requirements of band width and isolation. Combining low unit loss characteristics with compactness and light weight, this new series of Kearfott Coaxial Isolators is available from present stock. Immediate selection and faster delivery is assured *. . . precision performance proven.*

A FEW OF THE TYPICAL SPECIFICATIONS

MODEL	FREQUENCY	ISOLATION	INSERTION LOSS	VSWR
C991100-402	1.2—2.6 KMC	10 DB Min.	1.0 DB Max.	1.20
C992100-405	2.0—2.5 KMC	30 DB Min.	.8 DB Max.	1.20
C992100-404	2.0—4.0 KMC	10 DB Min.	1.0 DB Max.	1.20
C992100-407	3.0—3.5 KMC	35 DB Min.	.8 DB Max.	1.20
C993100-401	4.0—8.0 KMC	10 DB Min.	1.0 DB Max.	1.20
C994100-403	7.0—9.0 KMC	25 DB Min.	.8 DB Max.	1.20

Complete information on these or all of the models is available by directing inquiries to: 14844 Oxnard Street, Van Nuys, California, or the sales office in your area.

KEARFOTT DIVISION
GENERAL PRECISION, INC.

Little Falls, New Jersey

SALES OFFICES SEATTLE, WASH. VAN NUYS, CALIF. PHOENIX, ARIZ. DAYTON, OHIO CLIFTON, N.J.
PALO ALTO, CALIF. SAN DIEGO, CALIF. DALLAS, TEX. CHICAGO, ILL. WASHINGTON, D.C.

Circle Reader Service Card 50

New Products

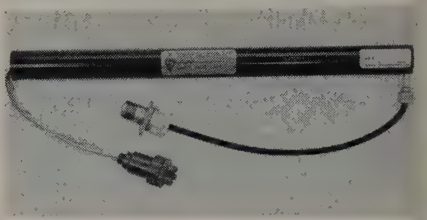
(*Continued from page 92*)

delivery of the pressurized air to the transmission system. Application of these drying principles reduces the relative humidity of ambient air from 100 per cent at high temperatures to less than 2 per cent at 70°F.

Circle Reader Service Card 108

—*mwj*—

BACKWARD WAVE OSCILLATOR AVAILABLE FOR 10-15 KMC



Providing a power output level of 10 milliwatts and higher over the frequency range from 10 - 15.5 kMc, a new backward wave oscillator, Model OD 10-15, is now available from Stewart Engineering Corp., Santa Cruz, Cal.

The new tube, latest in a family of Stewart high-performance BWOs, offers wide-range electronic tunability with highly uniform, accurately reproducible characteristics.

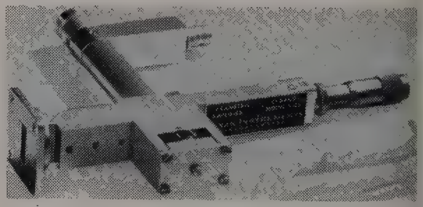
The Model OD 10-15 tube is a hard glass and metal, high-vacuum, helix type backward wave oscillator. It provides an exceptionally uniform power output vs frequency relationship, and is thus a suitable signal source for microwave swept signal generators and similar test equipment. It is designed also for service in countermeasures equipment, in receivers and transmitters requiring rapid programmed swept signal excursions, and in related military and research applications.

Output connection is an "M" band waveguide on RG55U coaxial cable. The power input cable terminates in a type PM6P hooded plug.

Circle Reader Service Card 109

—*mwj*—

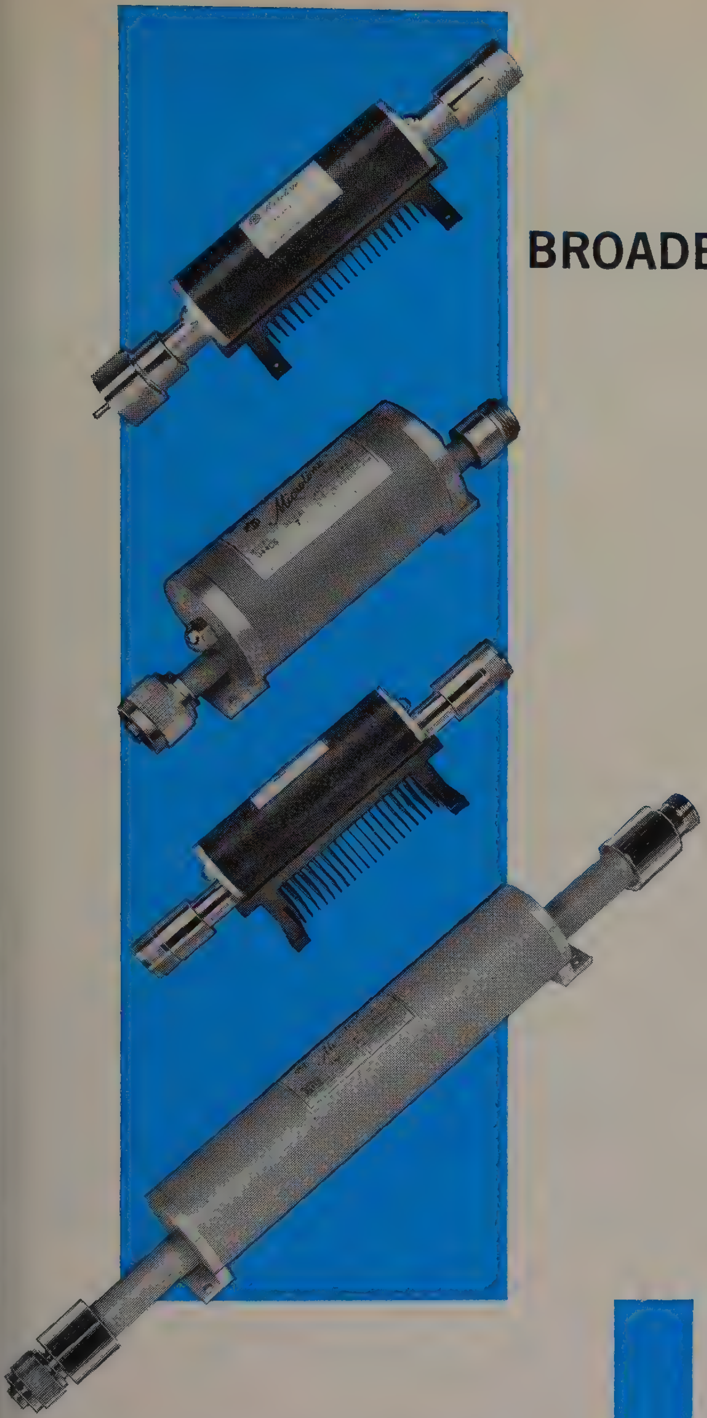
AMPLIFIERS USED AT L, S, C, X BANDS



A family of broadband, Mil Spec parametric amplifiers for applications at L, S, C and X bands is available now from Texas Instruments, Dallas, Tex. Among these is an S-band non-degenerate model that gives bandwidths up to 75 Mc at 15 db gain.

TI engineers report that extra wide bandwidth has been achieved by double tuning of amplifier idler circuits. Noise

(*Continued on page 96*)



BROADBAND COAXIAL ISOLATORS

- Coaxial isolators, an original Sperry breakthrough, providing 10 to 1 isolation to insertion loss ratios, are available with octave bandwidth coverage at 200 w power levels, as well as low power general purpose units. Coaxial isolators with other extreme specification requirements are also available on special order.

As radar components, and for countermeasure and communication systems, and other applications requiring the utmost in performance, Sperry broadband coaxial isolators are playing and will continue to play an increasingly-important role.

Extensive ferrite research and development in a fully-equipped materials laboratory is a dominant factor in the high performance characteristics of the Sperry broadband coaxial ferrite isolators.

Garnet and yttrium garnet materials are also available in ½″ x 1″ x 6″ bars.

We welcome your inquiries for more specific information.

HIGH POWER BROADBAND FERRITE COAXIAL ISOLATORS

MODEL NUMBER	FREQUENCY KMC	AVERAGE POWER	MAX. db INS. LOSS	MIN. db ISOLATION
D44L2-7	.95-2.35	200W	1	10
D44L6	1.25-1.365	200W	1	10
D44S2	2.00-4.00	200W	1	10
D44S2-5	2.34-5.00	200W	1	10

LOW POWER BROADBAND FERRITE COAXIAL ISOLATORS

MODEL NUMBER	FREQUENCY KMC	AVERAGE POWER	MAX. db INS. LOSS	MIN. db ISOLATION
72L2	1-2	10W	1	10
72S2	2-4	10W	1	10
72C2	4-7	10W	1	10
72H2	7-11	10W	1	10
D44S5-1	2-4	10W	1.5	20

SPERRY

SPERRY MICROWAVE ELECTRONICS COMPANY, *CLEARWATER, FLORIDA • DIVISION OF SPERRY RAND CORPORATION*

Microline Instruments • Radar Test Sets • Systems Instrumentation • ***Solid State Devices and Materials*** *• Microwave Components and Antennas*

Circle Reader Service Card 51

New Products

(Continued from page 94)

figure, including circulator loss, for TI's S-band model is 3 db over the frequency range of 2.8 to 2.96Gc; gain variation is no greater than 3 db over the Mil-spec temperature range of −40°C to +50°C.

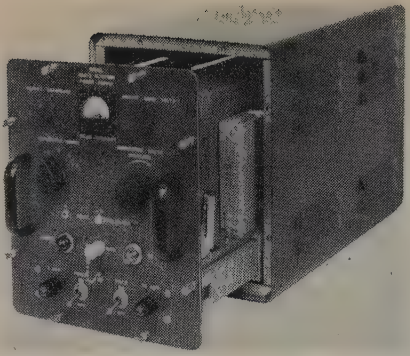
The unit also meets the vibration requirements of MIL-E-5400D. Operation under these environmental conditions is possible because small shifts of center frequency can be tolerated since the amplifier's passband is considerably larger than that required by an incoming signal. Within the range of characteristics available in this design, using presently available components, noise figures degrade slightly at the upper temperature limits and are dependent on the bandwidth required.

Circle Reader Service Card 110

—*mwj*—

POWER SUPPLY DESIGNED FOR PARAMETRIC AMPLIFIER APPLICATIONS

A regulated power supply (MA-2S) designed to provide ultra-stable klystron pump oscillator voltages for parametric amplifier applications and to insure minimum klystron frequency drift, is available from Microwave Associates, Inc., Burlington, Mass.



The MA-2S was designed for optimum operation under most field operating conditions, subject to unstabilized power lines. It compensates for both frequency and amplitude changes due to variation in line load.

The MA-2S power supply incorporates sophisticated regulating circuitry which provides reflector and beam voltage regulation on the order of 10 parts per 1000. Line voltage changes of ± 10 volts from the 115 volt operating level will not affect the operation of a parametric amplifier to any measurable degree when the MA-2S unit is used.

Circle Reader Service Card 111

—*mwj*—

LORAL DEVELOPS RADAR RANGE CALIBRATOR

A lightweight, portable test set for precision radar range calibration has been developed by Loral Electronics Corp., New York, N. Y.

The unit, designated Model #984-1001, provides calibrated marker pulses at fixed time intervals of 12.2, 122 and 1220 microseconds for ranges of 1, 10 and 100 nautical miles. A crystal-controlled oscillator provides an accuracy of ±0.02 per cent for all markers.

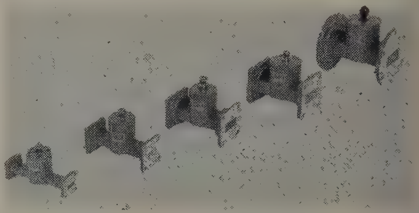
Features of the unit include: front panel adjustment of positive or negative output trigger and range marker pulses; independent front panel amplitude adjustment of trigger and range marker waveforms; modular construction; and 75 ohms output impedance for both trigger and video.

The Loral Radar Range Calibrator weighs 29 pounds, is approximately 16 inches x 8 inches x 11 inches and consumes 70 watts at 115 volts 50-60 cps. The unit is priced at $1280.00; quantity discount prices are available on request.

Circle Reader Service Card 112

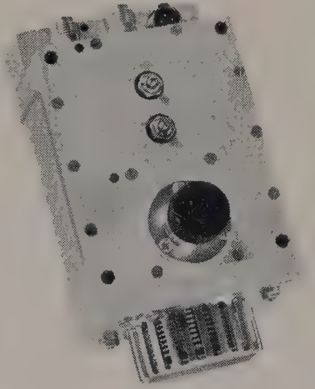
—*mwj*—

WAVEGUIDE SHORTING SWITCHES ANNOUNCED



Waveline Inc., Caldwell, N. J., announces a series of Waveguide Shorting Switches. The units are hand operated plunger type on/off switches that provide a convenient means of establishing a re-

(Continued on page 100)



NOW

WORLD'S SMALLEST
WORLD'S LIGHTEST
Size (21.7 in.^{3}) wt. 16.5 oz.

CONTINUOUS WAVE
L and S BAND AMPLIFIERS
for aerospace applications*

P-30 25w cw POWER AMPLIFIER

FEATURES

- Heat sink design
- Filtering and shielding of power supply leads
- Completely gold plated
- Light alloy fabrication
- All units can be used as building blocks stacked side by side on 4 surfaces.
- All electrical connections are on the top surface for convenience and multiple usage.

*ALSO IDEAL FOR G.S.E. APPLICATIONS

3CX100A5 CERAMIC-METAL PLANAR TRIODES

Model	Description	Typical Gain Between 218 and 1100mc: Low Power db	Output	High Power db	Output	Half Power Bandwidth In mc For High Power Operation	Power Requirements Plate
P-30	Power amplifier	16	2.5w	10	25w	15	600v @ .090a
X2-30	Frequency doubler	—	—	2.5	3w	8	300v @ .050a
X3-30	Frequency tripler	—	—	—1	2w	7	300v @ .050a
P-31	Power amplifier	N/A	N/A	10	50w**	15	1000v @ .090a

Heater is 6.3 v @ 1a for all units.
Vibration: 0.3 inch D.A. or a vector sum of 15g (whichever is less) transverse and longitudinal from 5 to 2000 cps.
**With 50w Power Output tube should be forced air cooled.

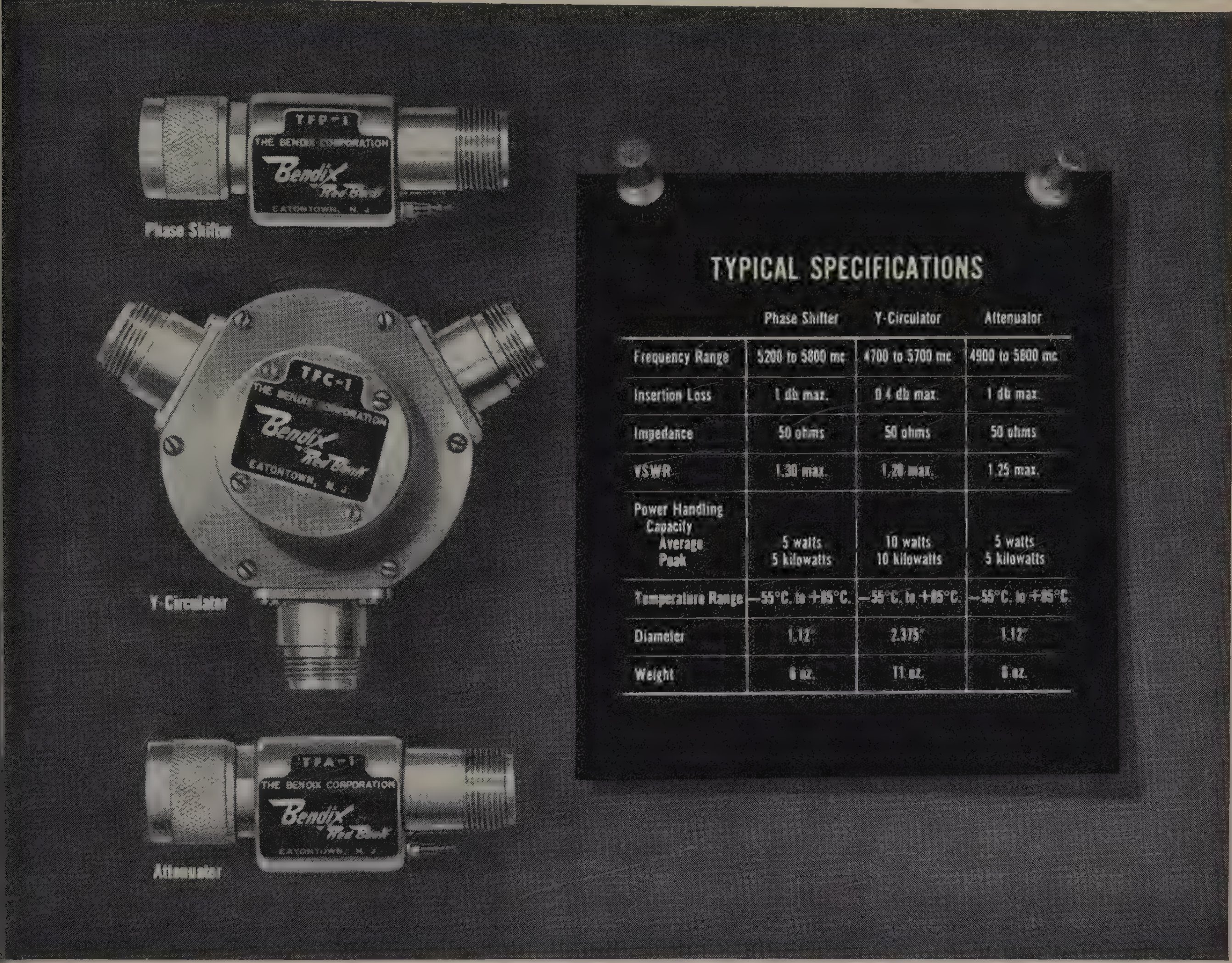
PRICE: $695.00
F.O.B. PASADENA, CALIFORNIA
For quantity prices contact RESDEL direct

RESDEL ENGINEERING CORPORATION
330 South Fair Oaks, Pasadena, California
Tele: MUrray 1-7689 SYcamore 5-5197

Send for free literature

Circle Reader Service Card 52

Bendix Craftsmanship at work for you


TFP-1
THE BENDIX CORPORATION
Bendix Red Bank
EATONTOWN, N. J.
Phase Shifter
TFC-1
THE BENDIX CORPORATION
Bendix Red Bank
EATONTOWN, N. J.
Y-Circulator
TFA-1
THE BENDIX CORPORATION
Bendix Red Bank
EATONTOWN, N. J.
Attenuator

TYPICAL SPECIFICATIONS

	Phase Shifter	Y-Circulator	Attenuator
Frequency Range	5200 to 5800 mc	4700 to 5700 mc	4900 to 5800 mc
Insertion Loss	1 db max.	0.4 db max.	1 db max.
Impedance	50 ohms	50 ohms	50 ohms
VSWR	1.30 max.	1.20 max.	1.25 max.
Power Handling Capacity			
Average	5 watts	10 watts	5 watts
Peak	5 kilowatts	10 kilowatts	5 kilowatts
Temperature Range	—55°C. to +85°C.	—55°C. to +85°C.	—55°C. to +85°C.
Diameter	1.12"	2.375"	1.12"
Weight	6 oz.	11 oz.	6 oz.

NEW BENDIX® MICROWAVE FERRITE DEVICES.* **1** The Electrically Variable Phase Shifter, TFP-1, can produce phase shifts in excess of 90° over a minimum bandwidth of 10%. Chief uses are as phase modulator, fast shift, and in a wide variety of r-f direction finding devices. **2** The Y-Circulator, TFC-1, offers at least 20 db isolation with less than 0.4 db insertion over bandwidth exceeding 20%. Ideal for use with masers, and parametric amplifiers. **3** The Electrically Variable Attenuator, TFA-1, has a range exceeding 25 db over a minimum bandwidth of 15%. Useful in fast AGC circuits and remote level control applications. Write today.

*PAT. PENDING

ELECTRON TUBE PRODUCTS
Red Bank Division
EATONTOWN, NEW JERSEY

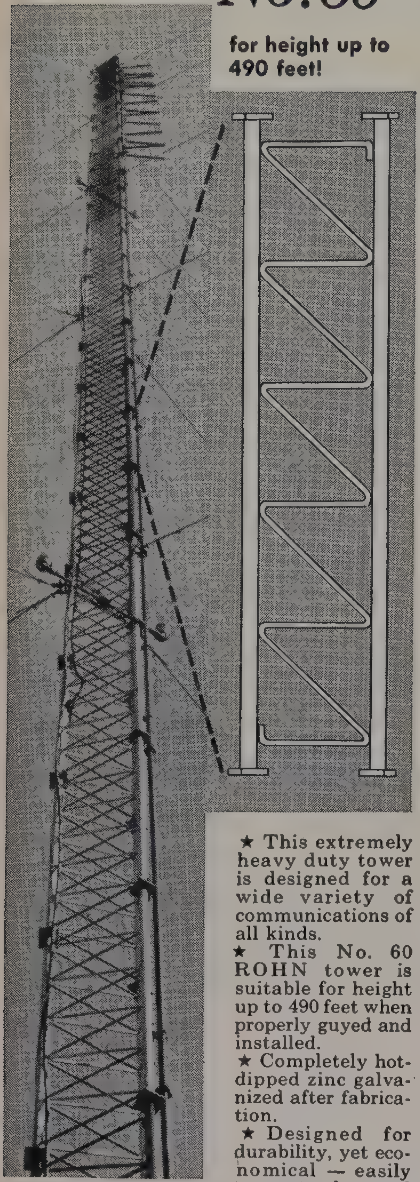
THE Bendix CORPORATION

Circle Reader Service Card 53

ROHN COMMUNICATION TOWER

No. 60

for height up to 490 feet!



★ This extremely heavy duty tower is designed for a wide variety of communications of all kinds.
★ This No. 60 ROHN tower is suitable for height up to 490 feet when properly guyed and installed.
★ Completely hot-dipped zinc galvanized after fabrication.
★ Designed for durability, yet economical — easily erected and shipped. ROHN towers have excellent workmanship, construction and design. Each section is 10 feet in length.

Shown above is a ROHN No. 60G tower used for FM broadcasting, installed to a height of 300 feet.

FREE

Details and complete engineering specifications gladly sent on request. Also ROHN representatives are coast-to-coast to assist you.

Write-Phone-Wire Today!

ROHN *Manufacturing Co.*

Box 2000
Peoria, Illinois
Phone 637-8416

"Pioneer Manufacturers of Towers of All Kinds"

Circle Reader Service Card 54

BOOK REVIEW

THE ANTENNA, *by L. Thourel, translated by H. de Laistre Banting; John Wiley & Sons. Reviewed by R. C. Hansen, Ph.D, Aerospace Corporation.*

A need is fulfilled to a great extent by this book: that of covering all phases of modern antenna technology without either the handbook treatment which omits the understanding of the basic phenomena, or the complete electromagnetic theory approach which obscures the operation of the system in complex algorithms for Maxwell's equations. Thus only plane vector wave solutions to Maxwell's equations are treated in this book and much mathematical detail, e.g., in the calculation of the field from dipoles, is not included. However, the depth of mathematical analysis in the less classical problems is quite adequate.

The division into chapters is by type of antenna, with the first two chapters covering introductory material. In order, the 16 chapters cover: definitions and fundamental relations; plane waves and boundary conditions; vertical wire antennas; theory of arrays; HF arrays; dipole type antennas; arrays of dipoles and squares, Yagis, and rhombics; end fire antennas; omnidirectional and broadband antennas; radiation from apertures; horns; paraboloids; fan beam antennas; slots; lenses; loops; and finally an appendix on transmission lines and reflection coefficient diagrams.

Rather than listing the topics covered in each chapter, it may be of more value to mention the strong and weak points of each. The first chapter covers important definitions and concepts such as gain, effective area, effective height, superposition, reciprocity, and radiation resistance. One minor omission is the relationship between radiation resistance, effective height, and directivity (or effective area) found, for example, in Jordan.

Chapter 2 includes all the important boundary situations in plane wave theory including polarization, images, and derivation of Fresnel's equations at a dielectric. Given the field of a short dipole, the third chapter derives the gain and radiation resistance, and the field of longer antennas. This is logically followed by VLF and LF antennas such as pylons and top-loaded monopoles. The array theory chapter contains a good mathematical treatment including Dolph-Tschebyscheff arrays and Hansen-Woodyard end fire arrays. A good feature is the depiction of graphical addition of vectors to show formation of main beam, nulls, and sidelobes. The book incorrectly states that the Dolph-Tschebyscheff array gives optimum gain. In fact, it gives optimum resolution (beamwidth). Chapter 4 does not mention optimum gain arrays, nor the supergain phenomenon. Also, the additional phase needed in a Hansen-Woodyard array is given in Equation 4.24 as π; it should be 2.94, a number obtained by numerical solution of the gain equation.

Chapter 6 (on dipoles) gives a good analysis of folded and delta fed dipoles, and of dipole bandwidth, among others. An extensive treatment of rhombics comprises most of Chapter 7; one new item is the Chireix-Mesny array of interconnected rhombics. The end fire antenna chapter includes some material on surface wave antennas including dielectric rod and "cigar" antennas. The hueristic treatment of Simon's cigar is probably the first to appear in a text. The aperture chapter treats both rectangular and circular apertures using conventional distributions: cosine-on-a-pedestal, $\cos^n \theta$, $(1-\rho^2)^n$. No mention is made of Taylor optimum resolution designs.

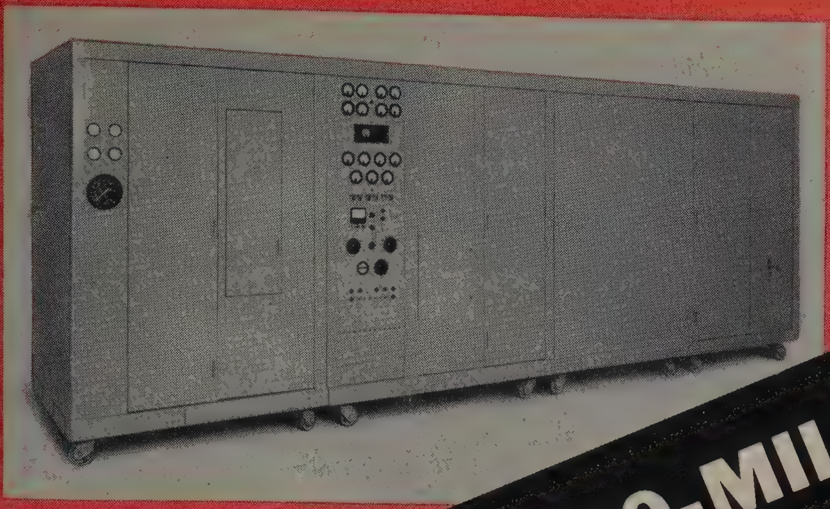
Included in the horn chapter are discussions of phase center and gain determination, and of the hoghorn, currently of interest as a very low noise design. The paraboloid chapter includes an excellent discussion of primary illumination and feeds, similar to that of Silver, and also includes short treatments on conical lobing and dimensional tolerance effects. It is postulated that dimensional changes due to expansion limit the ratio of diameter to average deviation (transverse, from ideal curve) to 10^4, giving a maximum realizable directivity from a paraboloid of 72 db. The material on slots includes a clear discussion of the vector Babinet principle. Some of the data in this chapter pertain to French guide and are not usable. The lens chapter includes, in addition to the usual derivations, sections on aplanatic lenses and artificial dielectrics.

The last chapter includes a calculation of the impedance of screened frames, (shielded loops) but unfortunately does not treat ferrite core loop antennas. In the appendix, useful transmission line relations are developed, and examples of impedance matching on a Smith chart are given.

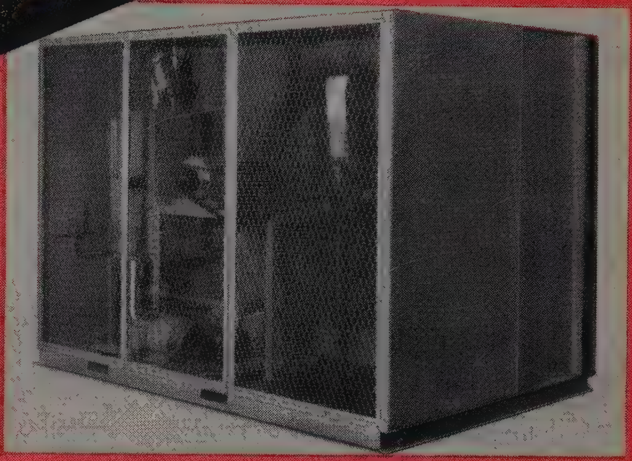
Two items of current importance not mentioned in the book are antenna noise temperature and electronic scanning. The book has a skimpy index and is, as might be expected, weak in English language references. The translation has a British flavor but is very readable.

Although much of the book is similar to portions of older books such as Silver, the collection of this material into one volume is useful; the book will serve as an intermediate level reference work for those not interested in the basic theoretical derivations. These derivations are found in the standard reference works, for example: Silver — *Microwave Antenna Theory & Practice,* for wave equation integration, diffraction, and apertures; Jordan — *Electromagnetic Waves & Radiating Systems,* for arrays, mutual impedance, and basic em theory; Stratton — *Electromagnetic Theory,* for modal wave solutions and complex boundary value problems; Schelkunoff & Friis — *Antennas Theory & Practice,* for impedance concepts and small antennas.

— m w j —



POWER FOR A 500-MILE TROPO HOP



These are views of the main power amplifier and heat exchanger—one of four sets of 75-kw troposcatter transmitters built to the exacting requirements of Air Force specification AN/FRC-39(V). Page Communications Engineers will install and operate them on the power-demanding 500-mile hop between England and northern Spain in the new Mediterranean communication network. Units utilize high-gain Varian klystrons to produce output directly with 5-watt drive; however, design permits use of similar Eimac tubes interchangeably. Sound like a Levinthal job? Well, it is, except that we've just changed our name to coordinate more suitably with our parent company. Now, it's Radiation at Stanford for high-power microwave packages.

Address us, for assistance with *your* problems, at 3180 Hanover St.,
Stanford Industrial Park, Palo Alto 7, California.

FORMERLY LEVINTHAL ELECTRONIC PRODUCTS INC.

RADIATION
at Stanford

Circle Reader Service Card 56

New Products

(*Continued from page 96*)

movable short in waveguide transmission systems.

A series of eight separate switches have been designed to operate over the frequency range of 2.6 to 40 kMc with the following characteristics: VSWR in the open position of 1.02 maximum; VSWR in the closed or short position of 125 minimum. Insertion loss is negligible in the open position. The devices are ruggedly constructed of standard waveguide with appropriate cover flanges and employ a positive action switching plunger to assure efficient dependable performance. In operation, a tight fitting plunger assembly is introduced into the waveguide section effectively sealing off the transmission system. When fully withdrawn in the open position the continuity of the waveguide walls is retained and full operation with minimum loss is maintained.

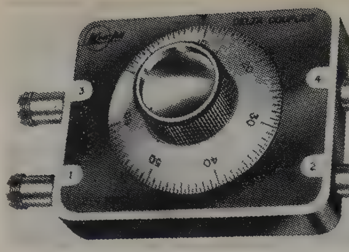
For special applications and upon special request these shorting switches can be equipped for remote control operation by incorporating a solenoid relay to actuate the plunger mechanism.

Circle Reader Service Card 113

—*m w j*—

KEARFOTT MARKETS VARIABLE BI-DIRECTIONAL COUPLER

A new broad band, precision calibrated variable directional coupler designated the Kearfott Delta Coupler has been announced by Kearfott Microwave Branch, General Precision, Inc., Van Nuys, Cal., manufacturers of microwave components and test equipment.



The instrument is adjustable from 5 to 70 db and may also be used as a precision variable attenuator over these ranges. Accuracy is assured to within ± 1 db of absolute attenuation over the specified frequency range and is displayed on a direct reading dial. The maximum power handling capability is 200 watts and low VSWR, low insertion loss and high directivity are inherent in the instrument. The Delta Coupler is available in frequency ranges from 500 to 1000 Mc through 4000 to 8000 Mc.

Circle Reader Service Card 114

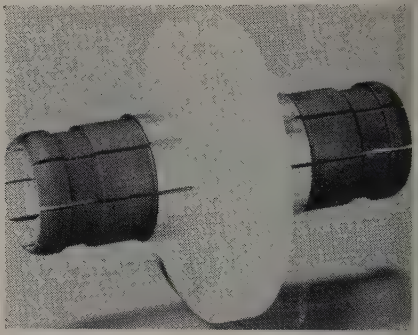
—*m w j*—

LUBRICATED COAXIAL CONNECTOR ELIMINATES GALLING PROBLEM

Prodelin, Inc., Kearny, N. J., has announced a new lubricated coaxial transmission line anchor insulator connector that assures, for the first time in the history of coaxials, the elimination of galling on bullet type inner conductor connector contact surfaces. This product was especially designed to eliminate high power transmission line failures caused by the galling of bullet contact surfaces resulting from differential expansion between inner and outer conductors.

Ordinarily, galling of bullet contact surfaces occurs during repetitive inne conductor movement over the bullet during the normal thermal expansion cycle of the transmission line. Formation of fin metallic "dust" particles on the ancho insulator creates a flashover hazard in th line.

The elimination of interruptions to service of installed rigid coaxial transmission lines, caused by galling, is based upon the use of an adherent lubricant designated as Prodelube #8. This metallic formulation is applied to the silver plated contact surfaces of the bullet. Prodelube #8 is a high temperature conductive material with highly efficient lubricating properties.



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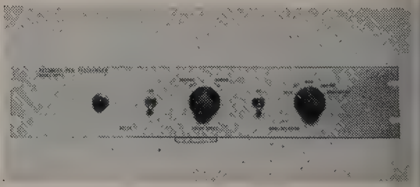
—*m w j*—

RECORDER PEN PROGRAMMER AVAILABLE



A recorder pen programmer for recorders using solenoid operated pen lif mechanisms is now available from Scientific-Atlanta, Inc., Atlanta, Ga.

Model RPP-1 Pen Programmer operate the pen lift in five distinct code pattern for trace identification. The programme is especially useful when the recording is to be reproduced photographically o by other methods.

The programmer is specifically designe for use with antenna pattern recorder and X-Y recorders where multiple recordings on the same chart are desired.

Weighing just eight pounds, mode RPP-1 is furnished in a standard 19-inch wide, 3 ½ inch high rack panel. Powe requirements are 115 volts, 50/60 cps, 1 watts.

Price of the programmer is $300 f.o.b Atlanta, Georgia with two to three week delivery.

Circle Reader Service Card 116

—*m w j*—

(*Continued on page 102*)

PRECISION WAVEGUIDE BENDING
TO YOUR SPECIFICATIONS
Bends, Twists, Offsets, Coils, Transitions, Fabrications and complete assemblies to your prints.

Specialty
AUTOMATIC MACHINE
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...of Supply and Demand, that is

MATCHING PRODUCTION TO NEED and ANTICIPATING REQUIREMENTS for PERFORMANCE IN TWTs

That's the main business of ME/c with an established capability for supplying advanced components

- **ME/c** offers a family of PPM-focused broadband, low-noise TWTs, S-band through $K\mu$-band with noise figure below 15 db.
- **ME/c** has another 'first' in the development of below 10 db noise figure PPM-focused, magnetically-shielded TWTs in S-, C- and X-bands.
- **ME/c** has at the ready 10 mw and 2 watt PPM-focused TWTs in C-, X- and $K\mu$-bands for ECM repeater and instrument amplifiers.
- **ME/c** serrodyne modulator TWTs are available in S-, C-, X- and $K\mu$-bands which provide sideband suppression greater than 35 db.
- **ME/c** can provide off-the-shelf delivery of improved performance tubes for replacement purposes in such laboratory instruments as the HP 492A, HP 494A, Alfred Model 504, Alfred Model 503 and Menlo Park Engineering Model TA-4.
- **ME/c** can furnish C-band, X-band and $K\mu$-band medium power amplifiers at the 5 watt and 10 watt CW level.
- **ME/c** metal-ceramic TWTs have withstood 15 g shock tests with no change in performance and provide less than 0.5 db AM under 10 g vibration tests up to 2000 cycles.

ME/c entire TWT line carries a 12-month prorated shelf warranty with a 6-month unconditional shelf warranty.

ME/c offers one of the best warranties in the TWT industry — 1500 hours prorated operating time with a 500-hour unconditional operating-time warranty on low-level tubes.

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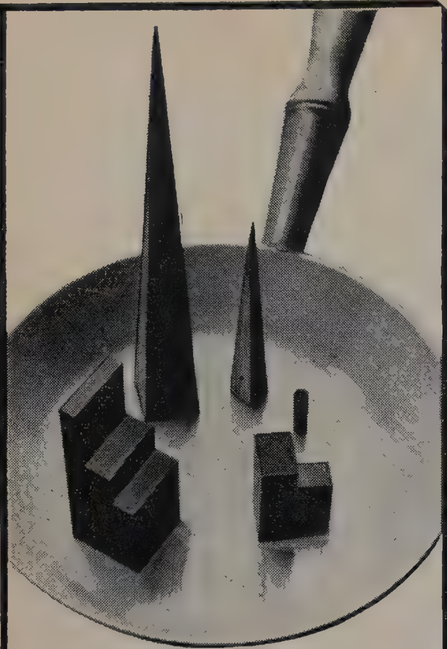

NEW CMA-415 PERMEABLE DIELECTRIC MAINTAINS THERMAL STABILITY TO 400°F

Custom Components' new microwave absorber is ideal for advanced system applications. High attenuation... easily molded or machined to specific tolerances... prompt service and deliveries to match your needs.

CUSTOM COMPONENTS, inc.

P.O. Box 248, Caldwell, N.J.
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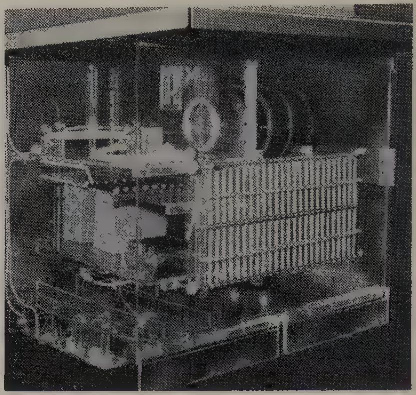
New Products

(Continued from page 100)

POWER SUPPLY HAS DIVERSE APPLICATIONS



A new dc power supply with an output range up to 350,000 volts, has been announced by Sorensen & Co., Inc., South Norwalk, Conn., a subsidiary of Raytheon Co.

The Sorensen Model 2350-8 is designed for diverse applications including dielectric testing of cables and klystron apparatus, for particle accelerators and the study of high-voltage discharges.

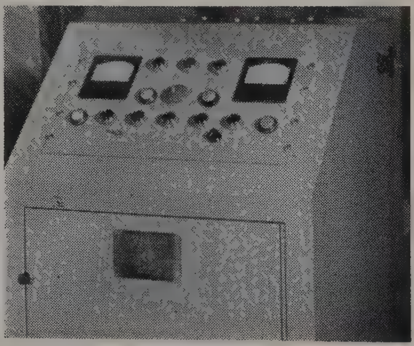
The unit is oil-insulated. Selenium rectifiers used in the unit increase reliability and reduce overall size and weight. The unit will provide continuous current of 8 milliamperes at any output voltage setting and offers 2 per cent RMS ripple. Auxiliary filters are available to reduce ripple down to 0.01 per cent.

Price of the unit is $13,500 and order-to-delivery time is approximately four months.

Circle Reader Service Card 117

—mwj—

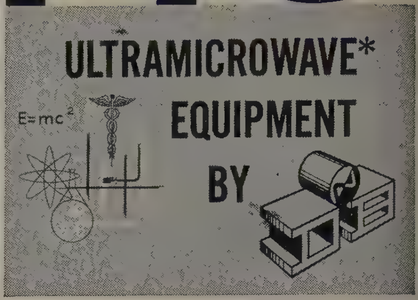
FXR OFFERS 10KV REGULATED MICROWAVE TUBE POWER SUPPLY



FXR, Inc., Woodside, N. Y., manufacturer of high power electronic equipment and microwave test instruments, has added a 10 kilo-volt high voltage regulated microwave tube power supply, model Z851-2, to its line.

The output voltage can be precision set from 0 to 10 kv, and current range is 0 to 100 ma. Ripple content is 0.4 per cent, maximum. An adjustable overload relay provides precision protection of a wide range and variety of components. Overload activation current is manually set

(Continued on page 104)



140 KMC

ULTRAMICROWAVE* EQUIPMENT BY

—it works

—it's accurate

—it's available

Complete data on request

DE MORNAY BONARDI

DE MORNAY—BONARDI
780 SOUTH ARROYO PARKWAY • PASADENA, CALIF.

*TRADE MARK De Mornay-Bonardi for its millimeter wave equipment

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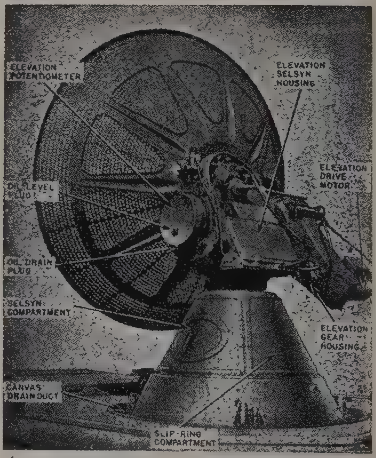

ANTENNA PEDESTAL SCR 584—MP 61B

Full azimuth and elevation sweeps. 360 degrees in azimuth. 210 degrees in elevation. Accurate to 1 mil. or better over system. Complete for full tracking response. Angle acceleration rate: AZ. 9 degrees per second squared EL. 4 degrees per second squared. Angle slewing rate: AZ 20 degrees per sec. EL. 10 degrees per sec. Angle tracking rate: 10 degrees per sec. Includes pedestal drives, selsyns, potentiometers, drive motors, control amplidynes. Excellent condition. Quantity in stock for immediate shipment. Ideal for missile & satellite tracking, antenna pattern ranges, radar systems, radio astronomy, any project requiring accurate response in elevation and azimuth.
Complete description in McGraw-Hill Radiation Laboratory Series, Volume I, page 284 and page 209, and Volume 26, page 233.

RADIO RESEARCH INSTRUMENT CO.

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NEW YORK
JUDSON 6-4691

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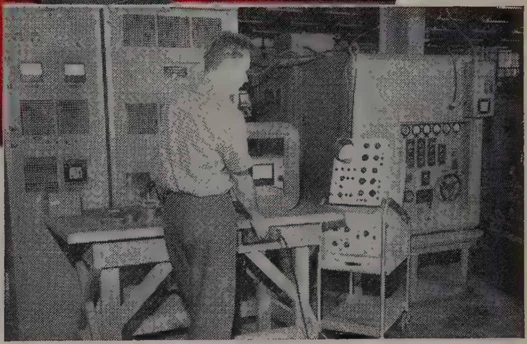
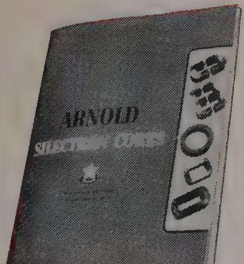


Arnold Pulse Transformer Cores are individually tested under actual pulse conditions

Here's technical data on

ARNOLD SILECTRON CORES



Bulletin SC-107 A . . . this newly-reprinted 52-page bulletin contains design information on Arnold Tape Cores wound from Silectron (grain-oriented silicon steel). It includes data on cut C and E cores, and uncut toroids and rectangular shapes. Sizes range from a fraction of an ounce to more than a hundred pounds, in standard tape thicknesses of 1, 2, 4 and 12 mils.

Cores are listed in the order of their power-handling capacity, to permit easier selection to fit your requirements, and curves showing the effect of impregnation on core material properties are included. A valuable addition to your engineering files—*write for your copy today.*

ADDRESS DEPT. MJ-2

The inset photograph above illustrates a special Arnold advantage: a 10-megawatt pulse-testing installation which enables us to test-prove pulse cores to an extent unequalled elsewhere in the industry.

For example, Arnold 1 mil Silectron "C" cores—supplied with a guaranteed minimum pulse permeability of 300—are tested at 0.25 microseconds, 1000 pulses per second, at a peak flux density of 2500 gausses. The 2 mil cores, with a guaranteed minimum pulse permeability of 600, receive standard tests at 2 microseconds, 400 pulses per second, at a peak flux density of 10,000 gausses.

The test equipment has a variable range which may enable us to make special tests duplicating the actual operating conditions of the transformer. The pulser permits tests at .05, .25, 2.0 and 10.0 microsecond pulse duration, at repetition rates varying anywhere from 50 to 1000 pulses per second.

This is just another of Arnold's facilities for better service on magnetic materials of all description. ● Let us supply *your* requirements. *The Arnold Engineering Company, Main Office & Plant, Marengo, Ill.*

ARNOLD

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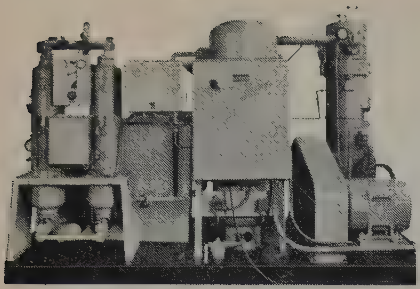

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Completely automatic, dependable Trinity Unitized Dry Air Systems eliminate the need for bottled gas, desiccant cartridge-changing, and provide a continuous flow of dry air for waveguide pressurization under all temperature and humidity conditions.

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INFORMATION

TRINITY

World leader in Dry Gas/Air Systems

TRINITY EQUIPMENT CORP.
Cortland, New York

Circle Reader Service Card 64

New Products

(*Continued from page 102*)

within the range 25 ma to 100 ma. Reference ground is selectable, either positive or negative, by a front panel control.

All controls and indicators are arranged for self-explanatory on/off control procedure and an oversized "panic" button offers a quick shut off in an emergency.

Input and output connectors are conveniently located at the side of the instrument which operates from 208 v.a.c., 3 phase, 60 c.

Model Z851-2 is priced at $3,500, with 60 to 90 days delivery.

Circle Reader Service Card 118

—*mwj*—

SPERRY ANNOUNCES MICROLINE 700 VOLT KLYSTRON POWER SUPPLY

KLYSTRON POWER SUPPLY MODEL 62A3
Microline

Sperry Microwave Electronics Co., Clearwater, Fla., has announced the availability of a new 700 volt Klystron Power Supply, Microline Model 62A3.

The unit was designed to fulfill laboratory requirements for the large majority of Klystrons requiring beam voltages not exceeding 700 volts.

Price is $550.

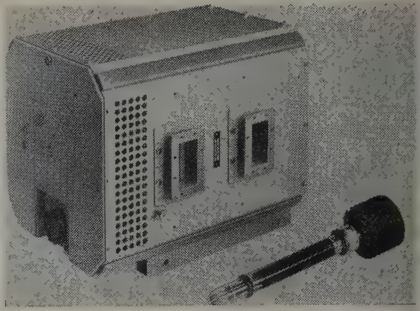
Circle Reader Service Card 119

—*mwj*—

AMPEREX TRAVELING-WAVE TUBE SUITED FOR UNATTENDED MICROWAVE STATIONS

Amperex Electronic Corp., Hicksville, L. I., N. Y., has announced the type 7537 traveling-wave tube. Guaranteed for a minimum life of 6000 hours, and operating as a broad band amplifier in the 4400 — 5000 Mc range, the 7537 is suited for unattended microwave stations.

Ease of maintenance is a feature of this tube. Mount and tube are so designed that input and output circuits remain matched when a new tube is inserted in the mount. Operating voltages need no adjustment when new tubes are inserted. For more than 80 per cent of the tubes, no focus adjustment will be needed. Where required, the focussing is done by adjusting two screws at one end of the mount. In about six months it is expected that production refinements now under way will make it possible to replace tubes with no adjustments whatsoever.



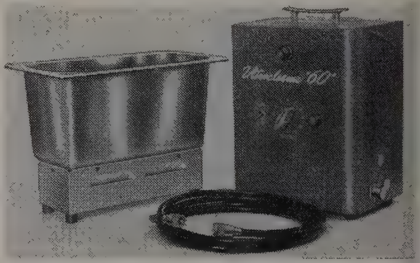
Adjustment is simple and well within the capabilities of the average technician. Tube replacement requires substantially less test and metering equipment, as well as installation time.

The 7537 can deliver a saturated power output of 6 watts. The low level gain at 5000 Mc, with the output power at 100 Mw, is better than 34 db. With the output power at 2.5 watts, the gain is better than 32 db.

Circle Reader Service Card 120

—*mwj*—

ULTRACLEANER #60 AVAILABLE IN FIVE SIZES



The Ultracleaner #60 line of sonic energy cleaners of the Lawrence Manufacturing Corp., Newark, N. J., has been broadened to include five new sizes with tank capacities up to 10 gallons for complete industrial cleaning needs.

The rugged construction of this new equipment allows for continuous use in mass production cleaning as well as single operation soil-removal from electronic, mechanical, optical and horological parts and assemblies.

Through the gentle but thorough scouring action of ultra-high-frequency sound waves, the Ultracleaner is particularly adapted to the cleaning of precision mechanisms and instruments, complex parts with blind holes, electronic and vacuum tube components, motor and generator parts, and printed circuit assemblies. It has been especially effective for special plating problems.

Circle Reader Service Card 121

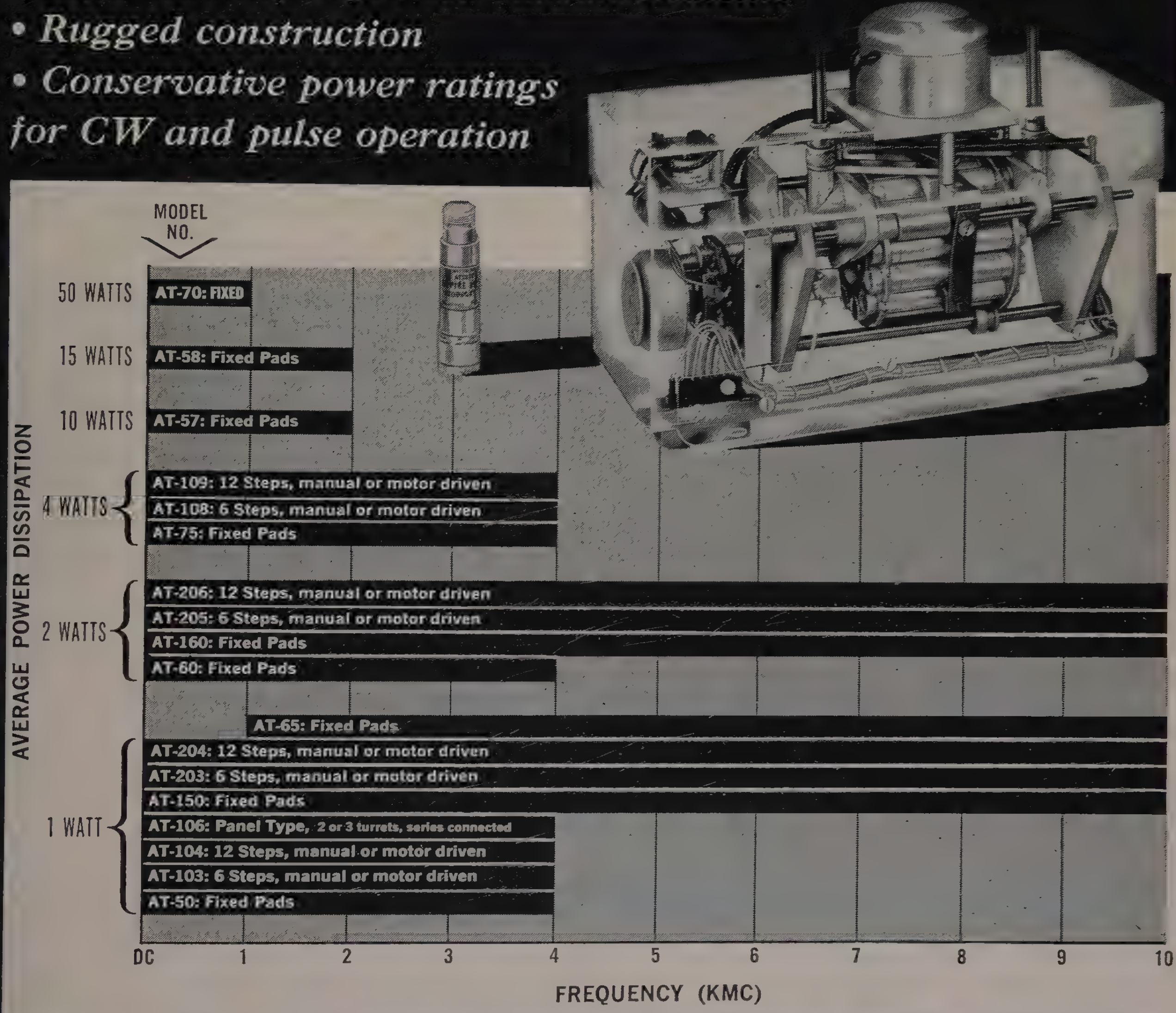
—*mwj*—

(*Continued on page 106*)

FROM A SINGLE FIXED PAD to a 12-POSITION AUTOMATIC STEP ATTENUATOR

...EMPIRE CAN MEET YOUR COAXIAL ATTENUATOR NEEDS... RATINGS FROM 1-50 WATTS... FOR OPERATION FROM DC TO 10 KMC

- *Low VSWR* • *Excellent accuracy* • *Optimum reliability*
- *High stability deposited carbon elements*
- *Rugged construction*
- *Conservative power ratings for CW and pulse operation*



For further technical information, send for Catalog 604 to:

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EMPIRE DEVICES, Inc.

AMSTERDAM, NEW YORK • VICTOR 2-8400

MANUFACTURERS OF: FIELD INTENSITY METERS • POWER DENSITY METERS • IMPULSE GENERATORS • COAXIAL ATTENUATORS • CRYSTAL MIXERS

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New TRAK Type 2959, 1.5 KMc, tuneable ±50 Mc
TRAK
Div. of C.G.S. Labs, Inc., Wilton, Connecticut
1
2

7 NEW Miniature MICROWAVE OSCILLATOR CAVITIES now available

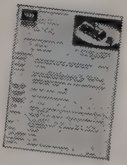
TRAK Electronics Company, Wilton, Connecticut, announces the formation of TRAK MICROWAVE CORPORATION to increase its developmental facilities for triode cavities in r-f signal generation from 500 Mc upwards. Present low, medium and high power cavities are available for application in grid pulse, plate pulse, and CW service.

TRAK expanded its Microwave Cavity line, which started in 1949, by adding the following 7 NEW miniature Cavities in 1960:

TRAK Type 9127-L	At 1090 Mc, tuneable ±25 Mc, available from 900—1200 Mc.
TRAK Type 2958	At 925 Mc, tuneable ±50 Mc, available from 500—2200 Mc.
TRAK Type 2959	At 1.5 KMc, tuneable ±50 Mc, available from 500—2200 Mc.
TRAK Type 9127-SL	At 2 KMc, tuneable ±100 Mc, available from 800—7000 Mc.
TRAK Type 9127-S	Available in 3 segments of S-Band: 2700—3000 Mc, 3000—3300 Mc, 3300—3600 Mc.
TRAK Type C-3136	Tuneable 2700—3400 Mc.
TRAK Type 9127-C	Tuneable 5400—5900 Mc.

ALSO, OSCILLATORS ENGINEERED to your specifications!

We invite you to write for **new** TRAK MICROWAVE CAVITY BULLETIN.



Cavity Oscillator ENGINEERS WANTED.
Resumes invited.

TRAK Microwave

TRAK MICROWAVE CORPORATION
Subsidiary of
TRAK Electronics Company
5006 N. Coolidge Avenue
Tampa 3, Florida
REdwood 6-6422

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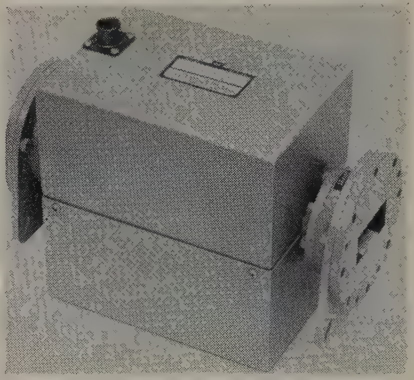
New Products

(*Continued from page 104*)

C-BAND VARIABLE FERRITE PHASE SHIFTER AVAILABLE



Cascade Research, Los Angeles, Cal., announces model G332 variable transverse field Phase Shifter which is capable of providing a phase shift range from 0° to more than 180°, over a frequency range of 5550 to 5750 megacycles with only 0.6 db insertion loss.

At a preset voltage, the unit maintains a phase shift setting within ±5°, over a temperature range of −20°C to +65°C.

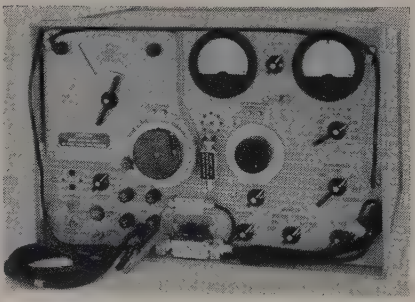
Additional specifications include: Maximum VSWR 1.30. Control voltage from 0 to 25 volts, with a maximum current of 200 milliamp. Power handling capabilities are 30 kilowatts peak and 30 watts avg. Shock and vibration are in accord with MIL-945A and MIL-STD-167. Mounting provisions are included, and special mountings as required are available.

The Model G332 C-Band Phase Shifter is useful for remotely controlling phase shift in antenna systems. Similar models can be made available at other frequency ranges.

Circle Reader Service Card 122

— *m w j* —

FLEXIBLE SIGNAL GENERATOR OFFERED BY SYSTEMS, INC.



A signal generator which offers complete flexibility through a wide range of frequencies is available for commercial use from Systems, Inc., Orlando, Fla.

Signal Generator — 12/U is a precision test instrument designed to provide f-m and unmodulated r-f signals for various measurements and alignment. One of the two output cables supplies output voltage at nine different crystal-controlled frequencies which coincide with the intermediate frequencies used by various receivers to be tested. The second output cable supplies r-f output signals in a frequency range of 20 - 100 Mc in five bands. The r-f output is variable from .05 - 10,000 microvolts; the i-f output, from .5 microvolt to 1 volt.

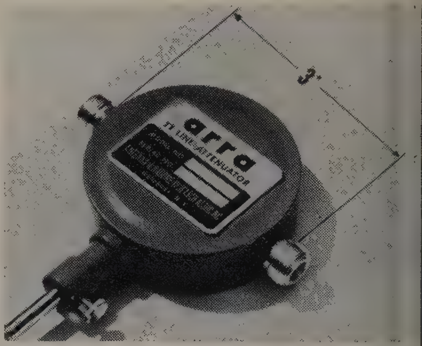
In view of this range, the signal gene ator can be used for many purposes in trouble shooting or testing, and can be applied to such things as oscillator calibration, sensitivity, signal plus noise to noise ratio, amplitude modulation rejection, overall distortion, power sensitivity alignment, i-f and r-f band pass characteristics and discriminator characteristics stage gain measurements and image rejection ratio.

Delivery can be made in 30 days; price is available on request.

Circle Reader Service Card 123

— *m w j* —

ATTENUATOR USED IN MISSILE APPLICATIONS



Antenna & Radome Research Associate (ARRA) Westbury, N. Y., has introduce a miniature 3 inch diameter "S" typ continuously variable π line attenuato The unit features small size and rugge construction for remote control missil and airborne applications. Designated a Model #4426-10, this unit is normall supplied with type N female connector However, type N male as well as BN & TNC male and female are availabl upon request.

Circle Reader Service Card 124

— *m w j* —

SPERRY CUTS SIZE, WEIGHT OF PPM-FOCUSED, X-BAND TWT

Sperry Electronic Tube Division o Sperry Rand Corp., Gainesville, Fla., ha announced production capability for i STX-264, similar in power output an drive characteristics to its longer, heavie predecessors, but significantly smaller an lighter.

It measures only 12 inches in overa length and weighs only 3 lbs. 8 ounces.

The rugged metal-ceramic constructio miniaturized envelope and temperatu compensation of the new X-band trave ing-wave tube make it suitable for appl

(*Continued on page 114*)

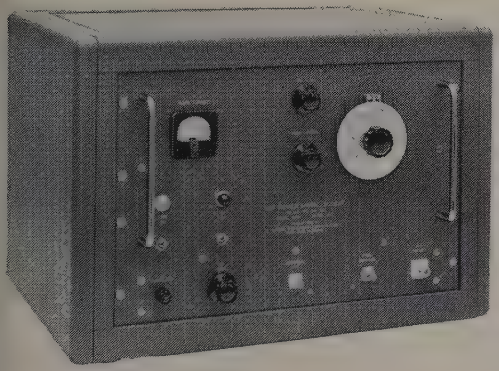
Delivery from stock

NEW VHF-UHF POWER SOURCES

FULL-RANGE STABILITY

50 WATTS OUTPUT

25 to 1,000 MC!



SPECIFICATIONS

Frequency range:	Model 215A-50, 25 to 50 MC Model 215A-150, 50 to 150 MC Model 215A-470, 150 to 470 MC Model 215A-1,000, 470 to 1,000
Power output:	50 watts nominal, 35 watts minimum into 50-ohm load, adjustable 20% to 100% of full power
Output stability:	± 5% after warmup
Frequency stability:	± 0.05% after warmup
Dial accuracy:	± 2% Models 215A-50/150 ± 3% Models 215A-470/1,000
Resetability:	0.1%
Modulation:	External AM
Price:	$3,300.00.

Data subject to change without notice. Price f.o.b. factory

Available in four off-the-shelf models covering the frequency range 25 to 1,000 MC, the new Sierra Electronic Corporation Model 215 Series VHF-UHF Power Sources provide extremely stable output to 50 watts. This unusual stability insures high repeatability for both routine check-out and precision laboratory work.

The instruments are continuously tunable over their respective ranges, offer high frequency stability and dependable operational stability under line voltage variation. Output power is adjustable 20% to 100% of rating. A plate current meter is provided for coupling adjustment, and a front-panel jack permits frequency monitoring with an external counter.

Sierra 215 Series Power Sources are easy to operate, completely self-contained and housed in sturdy bench cabinets. Rack mountable models also are available. They are ideal for accurate calibration of bi-directional power monitors and termination wattmeters, as well as for work in antenna design or other applications involving high attenuation of input signals.

For complete details, see your Sierra Representative or write direct.

sierra

SIERRA ELECTRONIC CORPORATION
A Division of Philco Corporation
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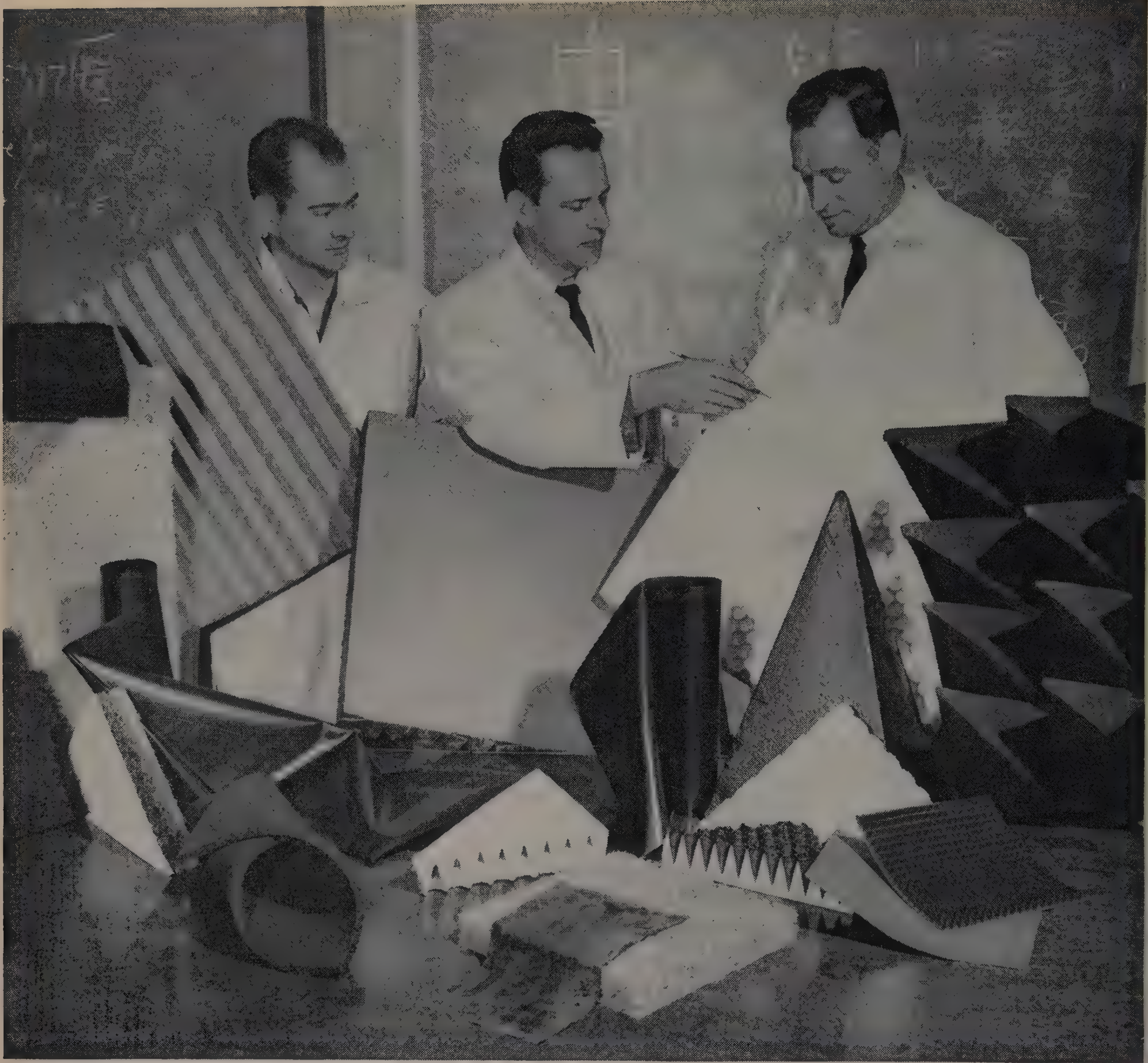


New B. F. Goodrich microwave absorber facilities improve testing reliability

Complete range of absorbers now available for accurate testing of components and systems

New facilities, recently completed by B.F.Goodrich, now offer a variety of broadband absorbers, resonant types tuned to desired frequency, and even complete anechoic chamber installations.

With these advanced products, plus the technical assistance of BFG specialists, you can now simulate free space conditions without leaving your location, provide year-round all-weather antenna testing, and eliminate undesirable reflections on antenna test ranges.

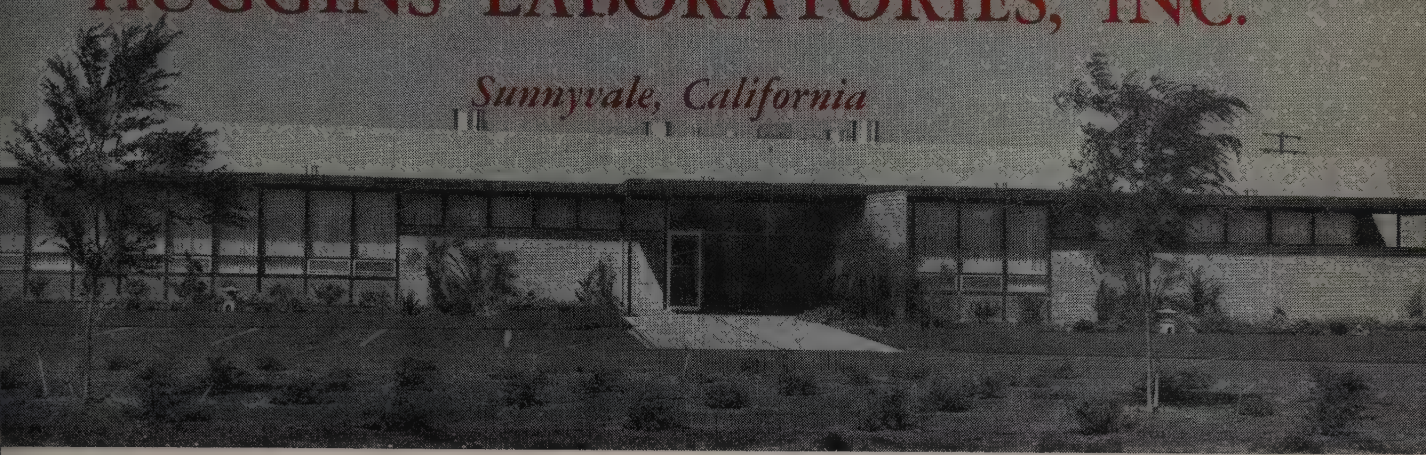
B.F.Goodrich microwave absorbers are made to exacting military specifications, and are carefully tested in our laboratory prior to shipment. For specifics on how we can help you improve radar performance, write *B. F. Goodrich Sponge Products, 130 Derby Place, Shelton, Conn.*

MICROWAVE ABSORBENTS BY B.F.Goodrich

Circle Reader Service Card 68

HUGGINS LABORATORIES, INC.

Sunnyvale, California



The story of a successful business rising from a shoestring start is anything but new to California's San Francisco Peninsula. Generally, the company histories exhibit a similar pattern. A strong individual or partnership with a desire to succeed in the electronic business converts a garage into a shop and launches his venture. Extreme cases are notable, however, and an initial capital nvestment of approximately three hundred dollars classifies Huggins Laboratories' rise to success as extreme.

In the story of Huggins Laboratories, the individual was R. A. Huggins, the year was 1948, and the garage was located in Menlo Park, California. Mr. Huggins had just received his MSEE from Stanford University fter having retired as a Commander in the United States Naval Reserve and receiving his BSEE from the University of California.

History

The first product manufactured in the garage shop was a very bright mercury arc lamp, developed by Mr. Huggins while he was working as a Research Associate n the Physics Department at Stanford University. Lamps of this type were used in high-speed wind tunnels for Schlierens, interferometers, and shadow-graph studies.

In mid-1948, all manufacturing equipment was moved rom the garage to a concrete block laboratory with 700 eet of floor space. This building was constructed by Mr. Huggins from the initial design to the completed building, including wiring, plumbing, and inspections.

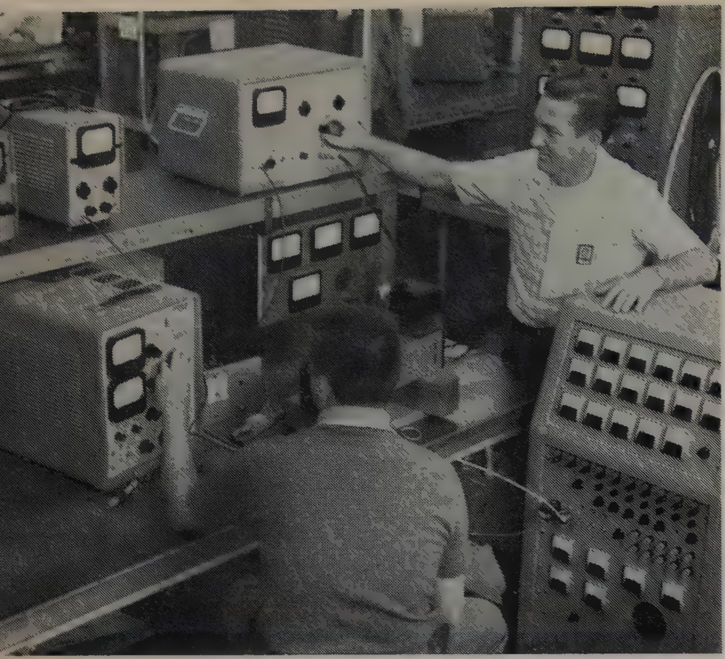
In addition to the mercury arc lamp project, work in he following years included developmental work on electronic components. One of these components was a bridge spectrophotometer that is now being used by the State of California for measuring the ripeness of tomaoes. Other projects included research work on vacuum ube components, and initial development work on traveling-wave tubes, which Mr. Huggins had studied during his graduate years at Stanford University.

In 1952, Mr. Huggins put his first traveling-wave tube on the market. This represented the first commercial vailability of this tube type. Original traveling wave ube work had been done in England during the war, and more recently had been further developed at the Bell Telephone Laboratories. In these early years of TWT work, Huggins Laboratories was aided by government study contracts which made possible the initial organization of production and research groups.

In expectation of business growth with this promising microwave device, Huggins Laboratories bought additional property adjacent to the existing land and doubled the original laboratory space. This was in 1953, and represented the Laboratories' first expansion program. The physical facilities and personnel were again doubled in 1954, 1955, and 1956, resulting in 16,000 square feet of floor space on a one acre lot.

In 1957, the plant was operated on a two shift basis, and plans were made for further facility expansion in order to meet customer requirements. This planning culminated in late 1958 in a ten mile move to Sunnyvale, California, where a modern building had been constructed. The new facility, built to Huggins' specifications, has 40,000 square feet of floor space, and is situated on a 15 acre site. The management prefers outright purchase to leasing arrangements, and owns the land, building, and all equipment housed in the building. This represents a net worth figured at slightly under 1½ million dollars. The working area is well planned and uncrowded, with space to accommodate 400 people, and having just under 250 at present. A pleasant, informal atmosphere prevails, which is due in part to the minimum of written rules and regulations. The close-knit feeling common to a smaller company is augmented by the minimum of authority exhibited by the management. The growth and company achievements are by-and-large credited to the employees. Added incentive is offered indirectly through liberal benefits and job improvements, and directly by a company profit sharing plan for which all employees are eligible.

The six year period from 1952 to 1958 represented rapid growth years. The decision had been made to produce traveling-wave tubes, and expansion to gear the Laboratory to production requirements was notable. During 1959 and 1960, product diversification has strength-



Technicians check a solenoid focused traveling wave tube in the R & D test area.

ened Huggins' status as the leader in the manufacture of traveling-wave tubes. Since its beginning as a TWT manufacturer, Huggins Laboratories has made many notable commercial firsts available to the industry. Besides the first traveling-wave tube, these include the first backward wave oscillators, first low-noise tubes, first periodic permanent magnet focused tubes, and the first electrostatic focused tubes.

During the early years, Huggins Laboratories, practically alone, made TWT's (both forward wave amplifiers and backward wave oscillators) available to the system engineers. Immediate application potentials were obvious to those in the company, and turning this potential into application by making the tubes available in quantity is felt by management to be the major contribution of this Laboratory to the microwave field. Huggins Laboratories feels it has advanced the traveling-wave tube industry years ahead of its state if this contribution had not been made. In accomplishing this microwave industry service, the Laboratory developed the ability to take the best of government sponsored research in this field, add excellent engineering and technical know-how, and convert these ideas into operating tubes that could be used in the field.

The emphasis of the company in the past has been production oriented, backed up by a very fine development and techniques organization. This emphasis will continue in the future, but a shift of orientation is taking place at present to include a continually larger stress on R&D. This concentration of effort will continue to be exclusively on the traveling-wave tube, with major emphasis on forward wave amplifiers and secondary emphasis on backward wave tubes.

Out of this heavily stressed production-development activity, two company made assets have followed. The first is the ability to produce in quantity these tubes which have been developed, the second is a philosophy. The tubes manufactured include a complete line of low-noise amplifiers in the output power range of 10 milliwatts, a line of forward wave amplifiers in the 10 milliwatt and 1 watt range, and a line of 10 milliwatt backward wave oscillators covering the frequency spectrum from 500 Mc to 18,000 Mc. This frequency range and tube type coverage is matched by no other TWT manufacturer, and includes solenoid, periodic permanent magnet and electrostatic focusing for the 10 milliwatt and 1 watt series, plus periodic permanent magnet focusing for the line of medium-noise tubes across this frequency spectrum.

The company has achieved the industry's highes production figure, and processes the broadest line of TWTs in the industry. Over 87 basic and 345 special tube types are produced, covering the microwave frequencies from 250 to 20,000 Mc. According to a numerical tabulation by the Associated Electronic Industries for fiscal 1959-1960, Huggins Laboratories produced 40 to 50 per cent of all traveling-wave tubes sold in the category "Forward Wave Amplifiers-power output less than 100 watts". This percentage figure would be much higher if compared strictly with the competitive tubes in the 10 mw to 1 w saturation power output class that this Laboratory manufactures.

The second asset that has evolved is a company philosophy of doing business. While the product entails advanced calculus in its research and development, its manufacture and shipment embodies arithmetic. Here space charge calculations and electromagnetic field theory give way to considerations of overhead, per unit production, cost of sales, current assets, current liabilities, and profit. In this accounting and management area, just as in the R&D and manufacturing areas, responsibility falls in the hands of engineers. The General Manager, Business Manager, and Sales Manager are graduate engineers with practical experience in either the research, development, or manufacture of traveling-wave tubes.

Unless the battle of the retarded arithmetic is won, the company is lost. It is to this Laboratories' credit that the engineering and manufacturing excellence has been matched by accounting and management excellence. The team effort of the manufacturing, engineering, and accounting groups has contributed highly to the technical and economic success of the company.

Since the team is composed of individuals, it is Huggins Laboratories' doctrine that any large success is an

The senior management team of Huggins Laboratories includes left to right, V. D. Varenhorst, sales manager; D. E. MacKerrow, assistant director of research; W. S. Floyd, business manager; R. A. Huggins, president and general manager; and J. J Gilleran, plant manager.

integration of a multitude of personal individual successes. Management insists that each person, from the highest to the lowest position, be a success at his particular job, and grow and expand with it as the company grows and expands. This is a difficult doctrine to set forth, yet the proof of its operation is embodied in the company it has produced.

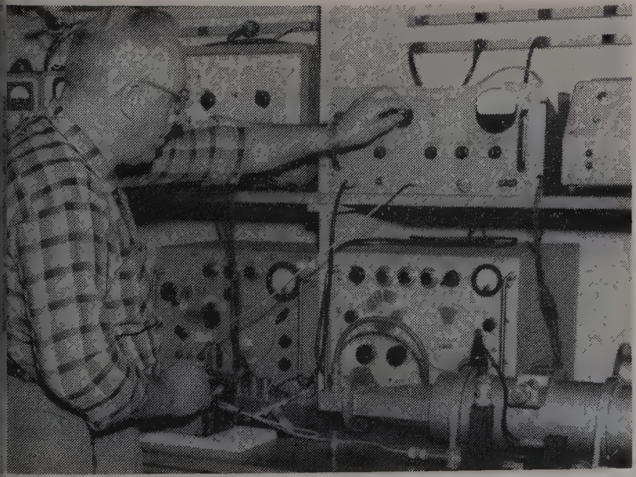
Operating Structure

Structurally, the company is divided into Senior Management; Accounting; Sales Department; Research and Development Department; Product Development Department; and Quality Control Department. The Senior Management team consists of Mr. R. A. Huggins, general manager and temporary director of research (present plans call for a man for the full-time position of director of research. This will allow Mr. Huggins to devote his full time to management activities); Mr. J. J. Gilleran, plant manager; Mr. V. D. Varenhorst, sales manager; Mr. D. E. MacKerrow, assistant director of research; and Mr. W. S. Floyd, business manager.

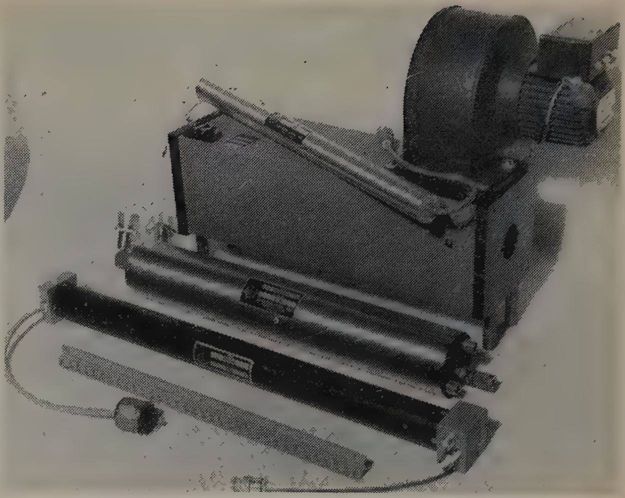
The sales program is under the direction of Vernon D. Varenhorst, sales manager. Mr. Varenhorst joined Huggins in 1955, became a project engineer, and in 1957 entered sales. This technical insight combined with a sales ability allow Mr. Varenhorst to guide the sales effort necessary for a small, specialized technical business. The Huggins Sales Department is augmented by sales representatives, having ten domestic and eleven foreign representatives.

The Accounting, Bookkeeping, and Contract Administration areas are under the direction of W. S. Floyd, business manager. Mr. Floyd is an engineering graduate with an additional degree in business administration.

As the company becomes more R&D oriented, research projects, both company and externally sponsored, become more prevalent. The Research Group is led at the present by assistant director of research D. E. MacKerrow, graduate engineer. Mr. MacKerrow was recently project engineer on the Huggins HA-58 electrostatically focused amplifier. This tube won an Award of Merit for industrial design at the 1960 Wescon Show. The Research Group is assisted in tube production by the facilities of the R&D Support Group under the direction of chemist R. B. Hanley. Combined here are the functions of an analytical chemical laboratory, machine and micro-machine shop, experimental glass blowing facility, and exhaust pump station. Many of the physical areas are climate-controlled and pressurized.



Project engineer W. S. Stringall in the production low-noise test area.



Three types of Huggins forward wave amplifiers. Top to bottom, HA-6 solenoid focused amplifier and associated solenoid; HA-20 ruggedized periodic permanent magnet focused amplifier; and HA-58 electrostatically focused amplifier.

The Product Development Department is headed by physicist W. B. Pruitt. The group does developmental engineering of existing products, utilizing research methods and ideas. Task areas include modification of tube electrical and physical characteristics to specific customer requests, and adaptation of tubes to meet military specifications. An environmental facility with vibration and shock testing equipment and a temperature chamber is the center of the program continually under-way to improve the ruggedness of tubes. Traveling-wave tubes have been developed which will exceed military environmental specifications, and will operate normally at 90,000 feet altitude; at shocks of 30 G; at 10 G vibration; and temperatures of −55 degrees C to +71 degrees C.

The Production Department is under plant manager J. J. Gilleran, one of the first twelve employees employed at the Laboratory. Mr. Gilleran has 36 years of electron tube experience; for twelve of those years he was in charge of the electron tube labs at the University of California and Stanford University. Although mass production of TWTs is impossible for most operations at the present state-of-the-art, simplified handling and production techniques minimize manufacturing and assembly time while maintaining adherence to quality standards. The Production Department is comprised of a machine shop, a drafting group, groups which wind helices, manufacture cathodes, blow glass vacuum envelopes, chemically process components, and assemble, align, and test both components and finished tubes.

The Quality Control Department maintains the strict final responsibility for the quality of the electrical and physical characteristics of tubes produced for the market. This department is led by Q. C. Manager, T. E. Butsko, a man with 31 years of electronics experience. Component quality control and inspections are stressed during tube manufacture. Each item is closely inspected for adherence to specification of part or assembly. As an example, an average of 25 per cent of the production time of each low-noise amplifier is spent in quality control, although

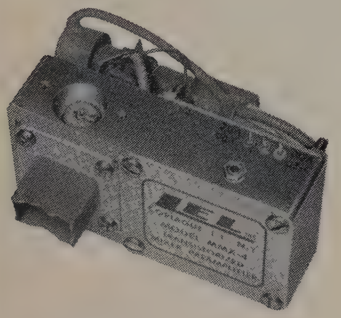
(Continued on page 112)

LOW NOISE

for
C Band

The MMC Series of Integrated Waveguide Mixer-Preamplifiers.

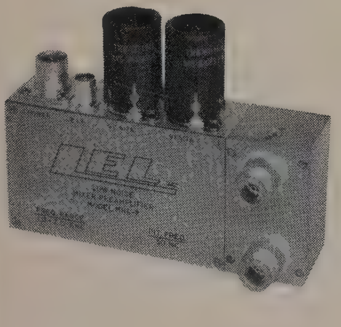
Noise Figure: 7.5db



for
X Band

The MMX Series of Integrated Microwave Mixer-Preamplifiers.

Noise Figure: 7.5db



for
L, S and C Bands

The MML, MMS and MMC Series of Coaxial Mixer-Preamplifiers.

Noise Figure: 7.5db

for
KA and KU Bands

The MMK Series of Integrated Microwave Mixer-Preamplifiers.

Noise Figure: 10.0db

LEL stocks the most complete line of low noise microwave Mixer-Preamplifiers available ANYWHERE.

Write for a comprehensive Microwave, IF, RF Amplifier Catalog.

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HUGGINS

(*Continued from page 111*)

not all quality control checks are conducted by the Q. C Department. The life of the tubes has been greatly extended, as observed by life tests continually in process in an effort toward further improvement.

Financial Structure

Huggins Laboratories was operated as a singly-owned proprietorship from 1948 to 1953, when it was incorporated in the State of California. Since over two thirds of the stock is held by the Huggins family, the Laboratory is basically a tightly-controlled, family-owned corporation. Unlike the popular trend, Huggins Laboratories is not considering any merger, acquisitions, or public financing. The Laboratory has experienced a period of unusual growth without resorting to public stock offerings.

Huggins Laboratories' Board of Directors consist of Mr. R. A. Huggins, president; Mr. E. F. Huggins, vice president; Mrs. G. L. Harrison, secretary-treasurer; and Mr. C. V. Litton, member of the board.

In addition to the health and welfare benefits that are standard for the industry, Huggins Laboratories offers two additional benefits that are worthy of note. They consist of a profit sharing plan and a stock purchase plan. In the profit sharing plan, 10 per cent of the company profits are returned to all employees on a monthly basis. This is computed proportionately on the basis of length of employment and present salary. These employee profit sharing plans are deep rooted in the electronics industry in this area, and contribute substantially to the success of the companies that employ them.

For those employees who wish to invest in the company, the opportunity exists to purchase stock in a company owned subsidiary, Menlo Park Engineering. This subsidiary is owned jointly by Huggins Laboratories and the employees of both companies. The stock is valued on a net worth basis, and may be purchased once a year or continually on a stock lay-away plan. The pricing of the stock in this manner in relation to the going rate makes this type of investment unique and quite profitable.

Menlo Park Engineering specializes in microwave instrumentation associated with wave tubes. The company is making traveling-wave tube equipment available to the microwave industry for both instrumentation purposes and system evaluation. At present, the company is diversifying into the field of light source instrumentation.

The size of the two companies is somewhat represented by last fiscal year's sales. Menlo Park Engineering has sales just under one million dollars, while Huggins Laboratories sales were approximately 3½ million dollars.

Summary

The build up of Huggins Laboratories to a yearly sales volume of 3½ million dollars, with a modern 40,000 square foot laboratory representing a 1½ million dollar capital investment has been accomplished through retained profits. The company has no other operating divisions or outside capital to finance their venture into the traveling-wave tube business. As such, Huggins Laboratories, Inc. represents the only TWT operation in the country that has bootstrapped itself from a three hundred dollar investment in a single car garage, to a leading position in the traveling-wave tube microwave field.

P-BAND

ELECTRONICALLY SWEPT SIGNAL SOURCE

MODEL 630-P

Another new electronically swept Signal Source joins our family.

The addition of the model 630-P extends the coverage one octave lower than before. The impressive frequency coverage of Wave Particle sweepers now extends from 400 MC to 70 GC in sixteen models.

The 630-P looks just like the other models and ightfully so. It contains similar electrical specifications to the others while providing a frequency coverage of one and one-half octaves in P band. Heart of the 630-P is the newly announced Eimac X-747, a highly compact permanent magnet ocused, voltage tunable magnetron. The X-747 plus Wave Particle experience and engineering add up to produce a P Band Sweeper to meet your needs.

If your needs also include Wave Tube Amplifiers and auxiliary equipment such as Microwave Levelers please contact us.

FOR ADDITIONAL TECHNICAL INFORMATION AND A DEMONSTRATION CONTACT YOUR NEAREST REPRESENTATIVE OR WRITE DIRECTLY

• FREQUENCY	400 - 1200 mcs
• OSCILLATOR	EIMAC X - 747
• SWEEP RATE	C.W. & 0.1-100 cps
• A.M. MODULATION	800-1200 CPS SQUARE WAVE
• SWEEP OUTPUT	LINEAR SAWTOOTH
• PRICE	$2850.00
• DELIVERY	4 - 6 WEEKS

Wave Particle Electronic Sweep Signal Sources

	freq. (GCS)		freq. (GCS)
630-P	0.40-12	640-X	8.0-11.0
630-L	0.98- 2.1	610-XKU	8.0-16.0
630-S	2.0- 4.0	620-KU	12.4-18.0
620-C	4.0- 8.0	610-K	18.0-27.0
630-CX	4.8- 9.6	611-K	15.5-24.0
620-X	7.5-11.0	600-KA	26.5-41.0
630-X	82-12.4	610-KA	27.0-40.0
631-X	7.0-11.0	600-V	63.0-75.0

wave particle

3221 FLORIDA AVENUE RICHMOND, CALIFORNIA

COAST TO COAST REPRESENTATIVES

THE THORSON CO. • 7361 MELROSE AVENUE, LOS ANGELES 46, CALIF. • Webster 4-1191

LAND-C-AIR SALES CO. • 72 MAIN STREET, TUCKAHOE, NEW YORK • Woodbine 1-4700

MICHAEL S. COLDWELL, INC. • 41 LANCASTER ROAD, NEEDHAM 92, MASS. • Hillcrest 4-1142

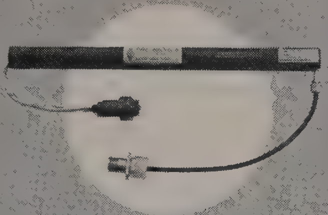
Circle Reader Service Card 70

very big in BWOs

Eight years ago, the first commercial backward wave oscillator took shape in the patient hands of wave tube pioneer Ray Stewart. With meticulous care and consummate skill, he evolved a precision lens system for forming a hollow electron beam, and developed techniques for producing a fantastically accurate helix pitch and placement relative to the beam.

The result was an oscillator of truly exceptional characteristics. But because Ray Stewart will never be satisfied with the merely exceptional, each BWO he builds . . . and he has built thousands . . . is better than the one before it.

This is the reason why Ray's BWOs can be guaranteed for 500 hours, and why they consistently outlive their guarantees. Ray's company is the only electron tube manufacturer devoted exclusively to the production of backward wave oscillators. The tube shown here is one of a series covering the frequency range 1-18 kmc.



Write for the new Stewart Engineering brochure and a set of specification sheets. When you've found out about the low operating costs of Stewart BWOs, we promise you'll be very big with your company's treasurer.

STEWART ENGINEERING CORPORATION

SANTA CRUZ • CALIF.

(*Continued from page 106*)

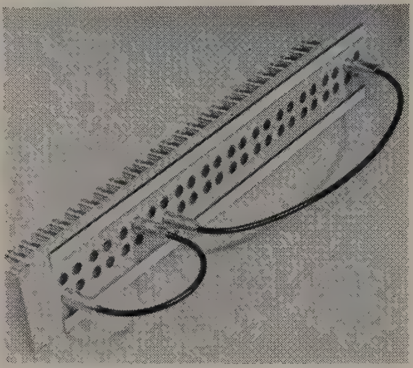
cations in broadband or multiple frequency systems, noise generators, and millimicrosecond switching devices.

Rated power output of the new tube is 1 watt minimum, with small signal gain of 30 db nominal. Input-output isolation is 75 db minimum. The STX-264 is fitted with Type N connectors for both input and output. Environment characteristics are excellent. It will withstand vibrations of 10 g's at 5-2000 cps. Shock toleration is 15 g's for 10ms. Performance is normal to altitudes of 70,000 feet.

Circle Reader Service Card 125

— m w j —

RF AND VIDEO PATCHING EQUIPMENT INTRODUCED



Trompeter Electronic Associates, Canoga Park, Cal., has introduced a line of 52 and 72 ohm coaxial jack strips and patch cords used for the routing of RF in receiver and low power transmitter installations, and the distribution of audio and video signals in data, computer, telemetry, communication and TV installations.

The rack mounted panels are usable for patching in coaxial systems of RG-8, 9, 11, 55, 58, 59, 62, and miniature coaxial cables. Each jack has a BNC fitting on the back for easy installation of the original cable and for making any subsequent changes. The jacks and plugs have large wiping and contact surfaces, and are heavily gold plated to insure perfect contact in the worst climatic and salt atmosphere conditions.

Panels are available with 12, 20, or 48 jacks and are priced at $123, $175, and $300 respectively, available 30-45 days ARO. Literature available on request.

Circle Reader Service Card 126

— m w j —

FERRITE USED FOR HIGH POWER APPLICATIONS

A nickel ferrite, KN 201, for use in microwave devices in the C-band range and above is announced by Kearfott Division, Microwave Branch, General Precision, Inc., Van Nuys, Cal.

The new material was developed specifically for high power applications where linearity is important. The ferrite material has properties in resonance isolators and Faraday rotation devices.

Since KN 201 has a curie temperature of 590° C, it is possible to use this material in devices which operate at very high ambient temperatures with little sensitivity to temperature changes. Principle characteristics also include a magnetization saturation point of 3,000 B_s, line width measured at 9300 Mc of 800, resonance field measured at 9.3 kMc, H_r of 2,800 (Gauss) and capabilities of obtaining front to back ratios in excess of 100/1.

Circle Reader Service Card 127

— m w j —

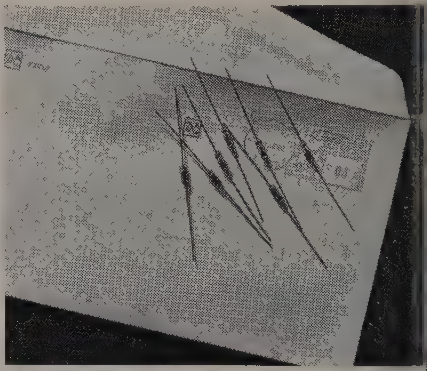
RF DIODES FEATURE ALL-GLASS, HERMETIC SEAL CONSTRUCTION

A series of six subminiature silicon point-contact diodes with all-glass construction, and designed for convenient use in miniature RF circuitry is available from Microwave Associates, Inc., Burlington, Mass.

All-glass construction in these diodes (1N830 through 1N833 series) assures a reliable hermetic seal, enables direct soldering to axial leads close to the diode shell, and also reduces shunt capacitance for improved RF bandwidth at microwave frequencies.

The 1N830 series are recommended for VHF and UHF video detection and general purpose RF rectification in coaxial and printed circuit applications.

The 1N831 series are designed for low-noise RF mixer applications at signal frequencies below 4000 Mc.



The 1N832 series are intended for printed circuit low-noise broadband mixer applications at frequencies between 4000 and 10,000 Mc. The 1N833 type is intended for low-level RF detector circuits at all RF frequencies below 10,000 Mc.

Circle Reader Service Card 128

— m w j —

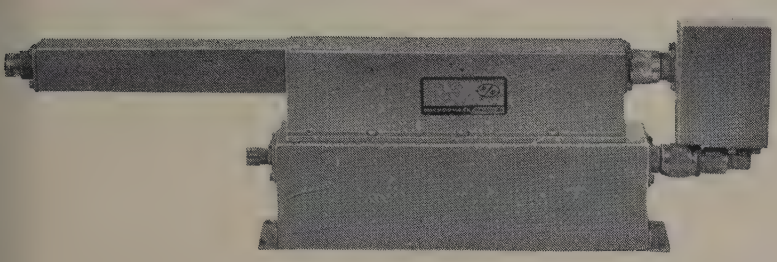
LFE OSCILLATORS PROVIDE ± 0.1 DB POWER STABILITY

Power stability approaching ± 0.1 db over a one hour period can be achieved with the new Series 814 Ultra-Stable Microwave Oscillators, according to new specifications released by the Instrument Division of Laboratory For Electronics, Inc., Boston, Mass.

(*Continued on page 116*)

Circle Reader Service Card 71

MC Harmonic Generators



MICROPHASE PART NUMBER CUH-4-150

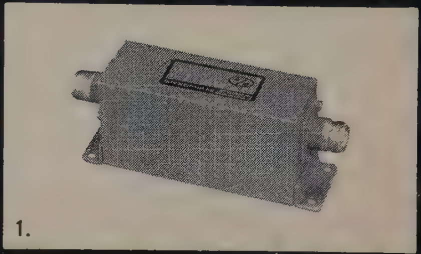
SPECIFICATIONS

INPUT-SIGNAL BAND	625-670 mc Fixed Tune
OUTPUT-SIGNAL BAND	2500-2680 mc Fixed Tune
ORDER OF HARMONIC OUTPUT	Fourth
INPUT SELECTIVITY	60 db 10% from Cutoff
OUTPUT SELECTIVITY	60 db 10% from Cutoff
EFFICIENCY	20 db ± 1.5 db
INPUT VSWR	1.7 max.
SPURIOUS OUTPUTS	60 db down min.

In an efficient harmonic generator, all but the desired frequencies must be reactively terminated. MICROPHASE harmonic generators are internally, selectively terminated resulting in a small, high performance unit. In addition, unwanted harmonics may be suppressed to any required degree.

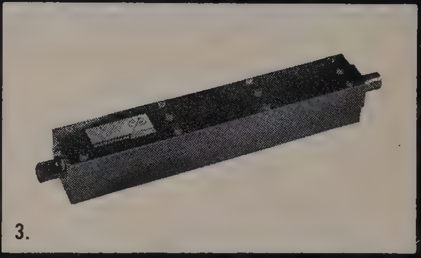
Harmonic generators in other frequency bands can be provided with orders of multiplication as high as twenty times the input frequency. Also, higher efficiencies over narrower bands may be achieved using similar techniques with varactor diodes.

OTHER MICROPHASE COMPONENTS



1.

2.



3.

1. **Bandpass Filter, Model CT133-182**—covers a passfrequency range of 300-360 mc with an insertion loss of less than 0.2 db and a maximum VSWR of 1.15:1. Filter provides attenuation of greater than 50 db from DC to 210 mc and from 550 to 1200 mc. Units with similar characteristics in VHF and UHF bands are also available.

2. **Low-Pass Filter, Model C12226**—has passband from DC to 2300 mc with 0.35 db maximum insertion loss and 1.25 maximum VSWR. This filter has 40 db attenuation at 2650 mc and 70 db minimum from 2900 to 11,000 mc. The overall length is 5½ inches.

3. **Harmonic Absorber, Model C1350L4**—in its stop band, absorbs energy instead of reflecting it. Has passband of DC to 1200 mc with a maximum insertion loss of 0.5 db and VSWR of 1.5 max. 50 db rejection for the second and third harmonic with a maximum stopband VSWR of 3.1. Filters with similar characteristics with sharper rolloff and broader stop bands, are also available.

MICROPHASE CORPORATION

Box 1166W Greenwich, Conn. NO 1-6200 WE 9-9190 TWX GNWICH CONN 759

Circle Reader Service Card 72

ELINT

ELectronic INTelligence — or more precisely, receiving systems for the collection of ELINT information — are of particular interest at ATI. Emphasis in current developments is on high sensitivity, combined with high probability of intercept for pulse signals.

While wide-open "crystal-video" receivers exhibit excellent intercept probability characteristics, they provide inadequate sensitivity for many operational situations. The sensitivity of this class of receivers can be increased significantly through the use of broad-band preamplification. The available tangential sensitivity is given by
$S_{max} \approx [-110 + F_{db} + 5 \log_{10}(2B_RB_V)]$ dbm
B_R, the RF bandwidth, and B_V, the video bandwidth are in Mc. The relation holds when B_R is at least twice B_V. F_{db} is the noise figure of the RF preamplifier, in decibels. The minimum preamplifier gain required to realize S_{max} is given by
$G_{min} = | S_{max} - S_x | + 3$db, where S_x is the tangential sensitivity of the crystal-video section, in dbm.

Our available ELINT receiving systems for frequencies ranging from 30 Mc to 40 kMc may be useful for your application directly or with minor modifications. If not, our staff of specialists in this area will be glad to tailor a new system to your particular operational situation. A project-oriented "chain of command" allows us to deliver on a short time scale.

ATI

AREAS OF SPECIALIZATION:
- ELINT Receiving Systems
- Deceptive Electronic Countermeasures
- Broad-Band Amplification
- Ionosphere Research Instrumentation
- Radio Astronomy Instrumentation
- Microwave Radiometry

APPLIED TECHNOLOGY, INC.
930 Industrial Avenue • Palo Alto, California

New Products

(*Continued from page 114*)

The steady operation of the 814 Stalos stems from the action of the AFC loop which stabilizes the klystron frequency. The klystron operates on the flat portion of the reflector mode corresponding to the desired frequency. As it is a voltage tunable oscillator, frequency control also produces corrections to power instability.

The one hour period may be exceeded if the unit is operated under constant line voltages and unvarying environmental conditions. No ferrite limiter or similar device is used in the 814's to restrict or control power output.

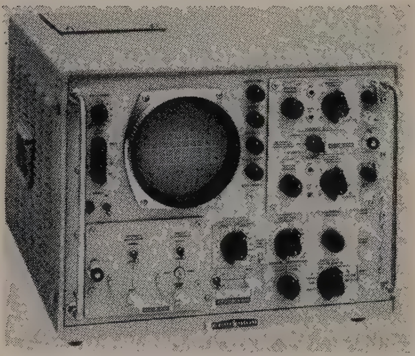
K-band capabilities of the Stalo Series have also been boosted to 26 kmc/s with a short-term frequency stability of five parts in 10^8 and long-term stabilities of one part in 10^6.

LFE's full range of Ultra-Stable Microwave Oscillators now encompasses the following equipments: three models in S-band from 2.5 — 4.8 kmc/s; eight models in C-band from 5.1 — 8.5 kmc/s; five models in X-band from 8.5 — 11.7 kmc/s; and, seven models in K-band from 12.0 — 26.0 kmc/s. Power outputs range from 50 mw to 1.5 watts.

Circle Reader Service Card 129

— *m w j* —

MILITARIZED 30 MC OSCILLOSCOPE OFFERED BY HEWLETT-PACKARD



A highly versatile 30 Mc oscilloscope built to military specifications is now available from Hewlett-Packard Co., Palo Alto, Cal.

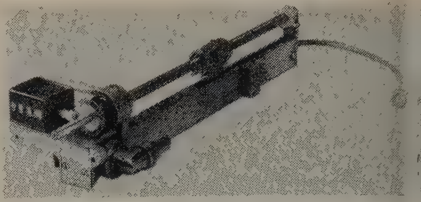
The new oscilloscope, Model 170A, is designed for general purpose measurements in both military and commercial applications. It is a rugged, dependable instrument meeting requirements of MIL-E-16400 and other military specifications for shock, vibration, humidity and temperature effects. Premium components are used throughout the instrument, and its high stability tube-transistor circuits assure long life and reliability.

In addition to accepting plug-in vertical amplifiers such as the Model 162A Dual Trace Amplifier with up to 20 mv/cm sensitivity and 14 nanosecond rise time, Model 170A has provision for a series of time axis plug-in units which enhance its versatility.

Circle Reader Service Card 130

— *m w j* —

IMPROVED L-BAND VARIABLE CALIBRATED ATTENUATOR AVAILABLE



Greater linearity over a wider bandwidth in the L-band range is now possible with the development of the Model 100 waveguide-beyond-cut-off type attenuato by the General Communication Co Boston, Mass.

The model features excellent mode filtering at lower values of attenuation Its general specifications and characteristics are as follows: linearity, 0.1 db pe 30 db; attenuation, adjustable over a 100 db range; insertion loss, approximately 25 db; and power dissipation, to 5 kw peak; and frequency range, 925 - 1225 Mc

Stops are provided to prevent operation in the non-linear region.

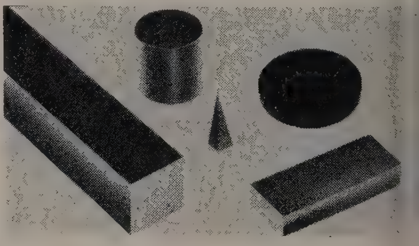
No load is supplied, but GCC's Mode 3001, 3051 or any other suitable termination may be employed. Other models, with knobs, varying cable lengths, and othe types of RF connectors, are available.

Circle Reader Service Card 131

— *m w j* —

"MICROLOSS" DEVELOPED BY COAX DEVICES

Coax Devices, Chelsea, Mass., announces development of "Microloss", new microwave absorbing plastic. Th material can be easily fabricated to form medium power attenuators, mode absorbing rings, cavity damping rings, absorbin covers for probing antennae, as a contro for amplitude distribution in antennae etc.



It can be used from —70° C t +150° C without any deterioration. I will not support fungus growth.

"Microloss" is available in 12 inc lengths in rectangular rods conforming t many waveguide internal dimension Round rods are also available. Othe shapes can be furnished upon request.

Prices on standard shapes vary fron $30 to $60.

Circle Reader Service Card 132

— *m w j* —

(*Continued on page 118*)

Circle Reader Service Card 73

Cast Waveguide COMPONENTS

complete line of high quality cast waveguide components is now available from Microwave Associates, Inc. nits for use at frequencies from 1.2 to 40 kMc are electrically and mechanically interchangeable with similar units ou may now be using. • Delivered from stock, they may be specified in either Beryllium Copper or Aluminum.

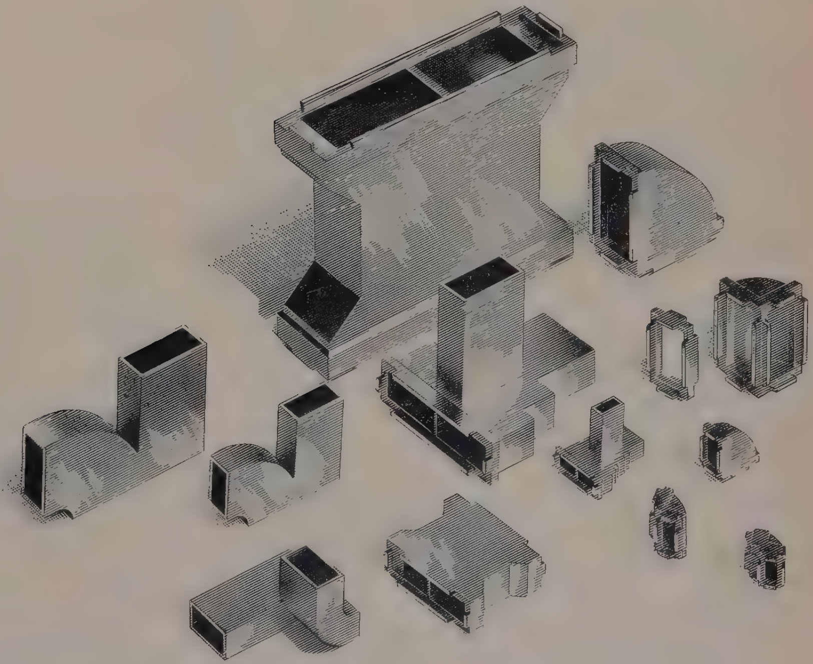
ICROWAVE ASSOCIATES, INC. Component Division

URLINGTON, MASSACHUSETTS • BROWNING 2-3000 • WESTERN UNION FAX • TWX: BURLINGTON, MASS. 942

icrowave Associates' Components Division also manufactures over 750 waveguide components. These include pressure windows, test equip-ent, specialized waveguide components such as balanced mixers, harmonic multipliers, and complete microwave sub-system packages.

EXPORT SALES: MICROWAVE INTERNATIONAL CORP., 36 W. 44TH ST., N.Y.C., N.Y., U.S.A., CABLE: MICROKEN

VISIT US AT THE
IRE SHOW
Booths 2302-2304



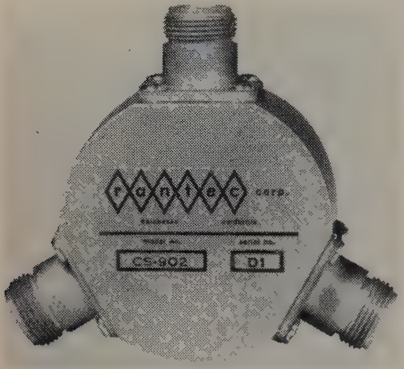
COMPENSATED CAST BENDS • WAVEGUIDE-TO-WAVEGUIDE COUPLINGS • "PANTY" ADAPTERS
E/H AND STRAIGHT ADAPTERS • FOLDED HYBRID TEES • SIDEWALL HYBRID COUPLERS

Circle Reader Service Card 80

New Products

(*Continued from page 116*)

Y-CIRCULATOR USED IN DUPLEXING SYSTEMS



Model CS-902, from Rantec Corp., Calabasas, Cal., is a lightweight, compact, broadband Y-Circulator for use in duplexing systems as well as with masers and parametric amplifiers. The unit covers the frequency range of 2.7 to 3.3 kMc with a minimum isolation of 20 db and a maximum insertion loss of 0.4 db. Isolation is considerably higher and insertion loss lower at band center. VSWR is 1.3:1 maximum and power handling is 5 kw peak.

By terminating one arm in a dummy load, the device can be used as a broad band isolator. With factory modifications it can be utilized as a switch, variable attenuator or amplitude modulator. Other models having the same specifications are available in the frequency ranges 5.4-6.7 kMc, 6.8-8.0 kMc, and 2.2-2.4 kMc.

Circle Reader Service Card 133

—*m w j*—

BRANCHED WAVEGUIDE DUPLEXERS AVAILABLE FROM BOMAC

Used in radar applications, a new branched waveguide duplexer, offered by Bomac Laboratories, Inc., Beverly, Mass., utilizes one TR and two ATR tubes to switch transmitter power to the antenna during the transmitted pulse while switching the incoming signal from the antenna to the receiver between pulses.

The use of two ATR tubes serves a double purpose: it minimizes incoming signal loss in the transmitter and eliminates the need for a critical transmitter line length. The single TR tube protects the receiver.

Shown here is a typical L-Band duplexer in 3.41 inch x 6.66 inch waveguide. Similar units are available for V, Ka, K, C, S and P-Bands. This L-Band duplexer is rated as follows: frequency, 1250-1350 Mc; transmitter power, 2 Mw max.; transmitter power (av.) 4 kw max.; VSWR, 1.6 max.; duplexer loss, 0.7 db; and weight, 49 lbs.

Circle Reader Service Card 134

—*m w j*—

OSCILLATORS USED AS SIGNAL SOURCES

Two new, stable microwave oscillato utilizing tunnel diodes in specially d signed circuits are now available fro RCA Electron Tube Division, Harriso N. J.

The oscillators, compact and ligh weight, are complete packages ready t use as signal sources, local oscillator etc., in applications where small size an long life are required.

The SS-100 is mechanically tuned ove its 1050 - 1400 Mc range. The cente frequency of the SS-104 is specified by th user in the range 800 - 1400 Mc. It ca be electronically tuned over a total rang of 5 per cent of its center frequency b varying the dc input voltage. Both osci lators require only 0.2 volt dc to produc several tenths of a milliwatt power outpu over their tuning ranges.

Circle Reader Service Card 135

—*m w j*—

(*Continued on page 120*)

J-V-M MICROWAVE

350 MODELS available!

MERCURY "10" SERIES of standard cavities triode

IMMEDIATE DELIVERY!

Low cost standard cavities produced to military specifications. Ranges from 220 to 6,000 MC, J-V-M quality cavities are designed for use as oscillators, amplifiers, doublers and triplers. CW or pulse using following tube types:

GL-7391 3CX100A5
GL-6442 2C39A
GL-6771 7554
GL-6299 7552

Quantity prices as low as **$20.00** ea.
F.O.B. Brookfield, Ill.

WRITE for complete data and catalog.

J-V-M MICROWAVE CO.

JVM
9300 W. 47th St.,
Brookfield, Ill.
P. O. Box 111,
TWX Brookfield 2796

Circle Reader Service Card 75

ALL SIZES

M S FLANGES

IN STOCK

THE FINEST QUALITY BRASS AND ALUMINUM STANDARD WAVEGUIDE FLANGES in stock at Formcraft—all precision made to military standards. For rigid and flexible waveguides.

Special flanges to your specifications. Send sketch or blueprint for a quotation.

SEND FOR NEW BROCHURE #14B DESCRIBING AND ILLUSTRATING ALL THE STOCK FLANGES

Formcraft TOOL CO

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Circle Reader Service Card 76

FIXED ATTENUATORS FROM STOCK FREQUENCY RANGES DC TO 12 KMC.

FROM OVER 7000 STOCK MICROWAVE COMPONENTS, MICROLAB NOW HAS AVAILABLE FIVE SERIES OF FIXED ATTENUATORS FOR IMMEDIATE ELIVERY WITH THE WIDEST CHOICE OF CONNECTORS AND ATTENUATION VALUES

SERIES
commended for component
l laboratory use from DC to
0 mc, the AA series atten-
ors are low cost, miniatur-
d, fixed pads. Units are
istructed of resistive ele-
nts in conventional pi type
cuits. They are bi-directional,
eptionally rugged, water-
of, and negligibly affected
temperature and humidity
inges. The PA series is iden-
al except for a 72 ohm
racteristic impedance.

AB SERIES
Designed for use in the DC to 5000 mc region, these units are exceptionally stable, bi-directional, and unaffected by temperature and humidity changes. The units are constructed of Microlab film resistors in conventional tee circuits. Operation to 5000 mc is possible due to the ultra-miniaturized resistors and advanced impedance matching techniques employed.

AC SERIES
These series of attenuators are miniaturized attenuation standards designed for use in the 4000 to 12000 mc region. Exceptionally stable and bi-directional, their small size and rugged mechanical properties provide a valuable component for systems applications. The units consist of a distributed lossy line contained within a coaxial housing.

AD SERIES
These attenuators are miniaturized medium power units designed for use in the DC to 4000 mc region. They are conservatively rated for a 15 watt power input under all specified environmental conditions. Units consist of two or more lumped tee sections cascaded to distribute the power dissipation. Cooling fins minimize the temperature rise.

FIXED ATTENUATORS

MICROLAB SERIES	AA	AB	AC	AD	PA
FREQUENCY RANGE (kmc)	0-3	0-5	4-12	0-4	0-3
ATTENUATION VALUES (db)	0-60	0-60	0-20	0-60	0-60
MAXIMUM VSWR	1.20	1.20	1.30	1.20	1.20
IMPEDANCE (ohms)	50	50	50	50	72
ACCURACY (db) (1)	—0.5 +1.2	—0.5 +0.5	—0.5 +0.5	—0.5 +1.0	—0.5 +1.2
POWER, AVERAGE (watts)	2	2	2	15	2
POWER, PEAK (kw)	2	3	3	3	2
OVERALL LENGTH (in) (1) (2)	2.2	2.7	3.2	5.1	2.2
WEIGHT (oz) (1) (2)	2.4	2.8	2.9	4.8	2.4
WATERPROOF	yes	yes	yes	yes	yes

Notes: (1) 10 db nominal (2) Type N connectors (3) All of the above are available with Types N, BNC, TNC, C and HN connectors

MICROLAB

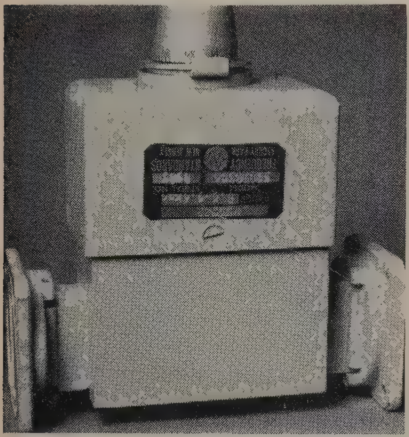
570
W. Mt. Pleasant
Avenue
Livingston, N. J.
WYman 2-5700

Circle Reader Service Card 77

New Products

(*Continued from page 118*)

X-BAND FILTERS AVAILABLE FROM FREQUENCY STANDARDS



Frequency Standards, Asbury Park, N. J., has announced that low loss tunable X-Band Filters are now available in various frequency ranges from 7000 to 10,000 Mc, assembled from stock. All filters feature a single tuning control and are available with a counterdial and calibration chart or screwdriver adjustment.

Drift is less than 3 cps/Mc/°C to suit most military applications. Two direct-coupled TE_3 mode cylindrical cavities are used, exhibiting an insertion loss of less than 2 db and a VSWR of less than 1.5 at F_0. Bandwidth is 8-12 Mc at the 3 db points and the filters provide a minimum rejection of 38 db at $F_0 \pm 60$ Mc.

Units are available with UG flanges or Coax connectors. Prices range from $350 to $400 each. Quantity discounts apply; delivery is two weeks.

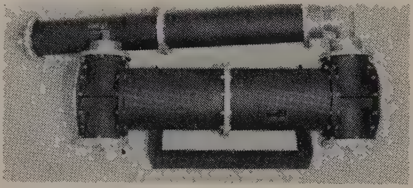
Circle Reader Service Card 136

—*mwj*—

UHF HIGH POWER HARMONIC FILTER DEVELOPED

Scanwell Laboratories, Inc., Springfield, Va., has recently developed a high power harmonic filter. The filter will attenuate harmonics in the output of a 20 kw transmitter which may be tuned to operate at a fundamental frequency anywhere in the band 225-400 Mc.

The new filter, designated model 303, is comprised of two filters — one variable and one fixed. The size of the variable filter sections is such that spurious pass bands exist above 600 Mc; the low-pass fixed portion is added to remove these spurious responses up to 2000 Mc.



Model 303 has three manual controls, two for impedance matching and one for cut-off frequency. All three controls are calibrated in terms of fundamental transmitter frequency and are set in accordanc with calibration curves which are supplied.

Circle Reader Service Card 137

—*mwj*—

BWO TUBE DESIGNED FOR TEST EQUIPMENT

Hughes Aircraft Co.'s microwave tub division is offering a new Ku-Band permanent magnet backward-wave oscillato designed for use in test equipment an commercial instrumentation, according t Robert T. Plummer, marketing manager.

Designated the Hughes 326H, the new tube is small and lightweight, with outpu characteristics which make it ideal fo application as a signal source for commercial test equipment, Plummer said.

The 326H has a 10 mw minimum output over a 12.4 to 18 kMc band with power rising to 65 mw in the center o the band. The oscillator requires no external cooling, with all electrodes isolate from each other and from the case.

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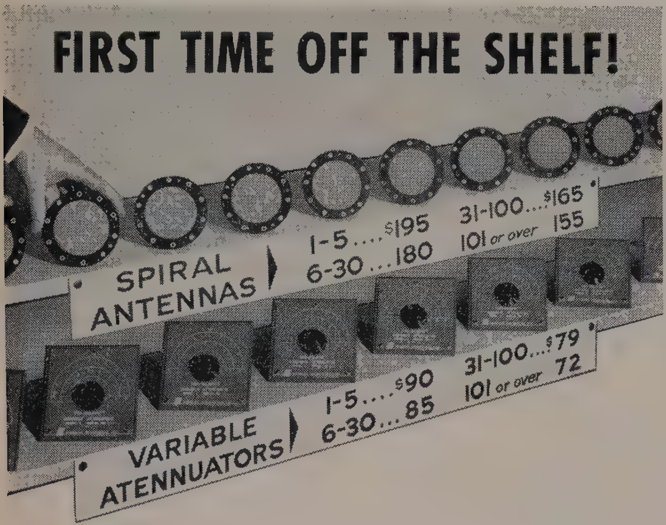

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NEW LITERATURE

NEREM RECORD AVAILABLE

The Boston Section of the IRE has an-ounced the availability of the NEREM Record. This 192 page volume contains 00 to 1000 word condensations, includ-ng all pertinent illustrations, of the 126 papers presented at the recent Northeast Electronics Research and Engineering meeting. The book is completely indexed, nd is bound in a stiff cover. Printing is etterpress.

Copies of the 1960 NEREM Record are vailable at $7.50 each from Boston Sec-ion IRE, 313 Washington St., Newton 58, Mass.

— m w j —

FERRITE ENGINEERING DATA SHEETS AVAILABLE FROM MICROWAVE ASSOCIATES, INC.

Availability of a new series of engineer-ng data sheets on high power ferrite circulators and broadband, low-power ferrite isolators has been announced by Microwave Associates, Inc., Burlington, Mass.

The two-color data sheets contain the latest information on electrical and me-chanical specifications for these micro-wave ferrite devices and include outline drawings with dimensions.

High power circulator bandwidths ange from 2700 - 2900 Mc/sec (MA-136) o 34,500 — 35,900 Mc/sec (MA-125). Low power isolator bandwidths range from 2600 - 3590 Mc/sec (MA-170) to 26,500 - 34,000 Mc/sec (MA-162).

The 21 detailed data sheets plus a short-form catalog covering over 80 ferrite devices and the complete product line of Microwave Associates' Electron Tube and Device Division will be sent on request.

Circle Reader Service Card 92

— m w j —

STEWART ENGINEERING OFFERS FACILITIES BROCHURE

A new six page brochure gives a profile of the facilities of Stewart Engineering Corp., Santa Cruz, Cal., with emphasis on the company's capabilities in the research, development, and manufacture of specialty vacuum tubes.

Circle Reader Service Card 93

— m w j —

ANDREW PREPARES RIGID LINE CATALOG

A 20 page catalog covering rigid coaxial transmission lines and associated equipment was recently distributed by Andrew Corp., Chicago, Ill.

The firm offers a selection of 50 ohm line and fittings in the size range from 7/8 inch to 9 inches. A new 3 1/8 inch coaxial transfer switch is introduced in Catalog R.

Circle Reader Service Card 94

— m w j —

COAXIAL CABLE CONNECTORS BROCHURE AVAILABLE FROM PHELPS DODGE

An eight page illustrated brochure describing new connectors for aluminum sheathed, high frequency Styroflex and Foamflex Coaxial Cables has been published by Phelps Dodge Copper Products Corp., New York, N. Y.

Full mechanical and electrical specifications along with typical installation instructions are given.

Circle Reader Service Card 95

— m w j —

MICROWAVE POWER ATTENUATOR BULLETIN AVAILABLE FROM EMPIRE DEVICES

A new two page, two color technical bulletin (No. 578) from Empire Devices, Inc., Amsterdam, N. Y., illustrates and describes two microwave power attenuators for the frequency range from dc-2000 Mc.

Designated Models AT-57 (continuous power rating 10 watts) and AT-58 (continuous power rating 15 watts), the units are intended for maximum attenuation up to 10 db when used alone, or up to 60 db when used in conjunction with Empire's AT-50 attenuator pads.

Engineering data provided includes typical applications, construction details and a description of special characteristics offered by these attenuators.

(Continued on page 122)

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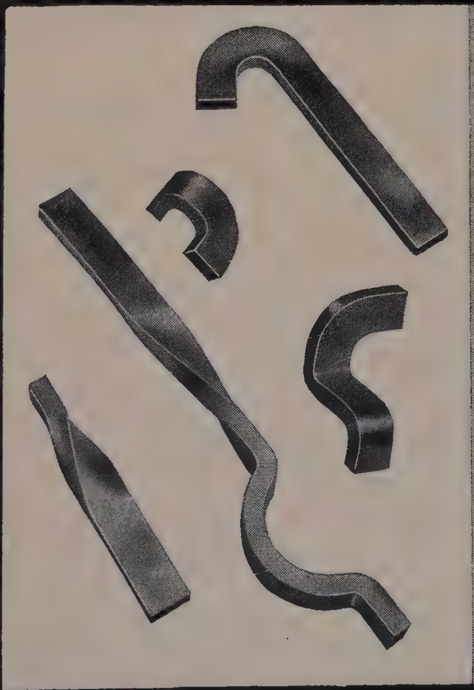

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New Literature

(*Continued from page 121*)

In tabular form the new bulletin give complete specifications on frequenc range, VSWR, accuracy, power ratings standard and optional connectors, an standard attenuation ratios available.

Dimensional drawings and ordering information are also provided.

Circle Reader Service Card 96

— *m w j* —

MILLIMETER - WAVE CATALOG ISSUED BY TRG, INC.

A new short form catalog featurin millimeter-wave ferrite devices and micr wave components in the 26 to 140 kM frequency range has been issued by TR Inc., Somerville, Mass.

This brochure contains technical dat on a variety of components designed t operate in the new upper limits of the r spectrum and includes ferrite isolators modulators, circulators and fast acting ferrite switches. A complete line of low loss TE_{01} circular waveguide bends an rotary joints is also described.

The catalog gives performance data o a complete line of test bench equipmen such as frequency meters, detector mount and attenuators, as well as technical dat on a new series of parabolic antennas fo the 26 to 140 kMc band.

Circle Reader Service Card 97

— *m w j* —

INFORMATION AVAILABLE ON D COUPLED DECADE AMPLIFIER

Information on an ac and dc couple decade amplifier is now available fron Quan-Tech Laboratories, Boonton, N. J.

The amplifier, Model 201-B, is a compact, stable, wide-range amplifier with controlled voltage gain of 10. With frequency response from dc to severa megacycles, the amplifier is suited for applications requiring low-noise level amplification with high input and low outpu impedance.

The literature provides complete specifications as well as technically descriptiv information.

Circle Reader Service Card 98

— *m w j* —

WAVEGUIDE PRESSURE WINDOWS DESCRIBED

A new bulletin describes the full line o waveguide pressure windows produced b Microwave Development Laboratories Inc., Wellesley, Mass.

Included in the illustrated bulletin ar full electrical and mechanical specifications, as well as complete dimensions, fo both solderable and flange-mounted windows. Applications, features, and specia production data for these waveguid pressure windows are described in detail

Copies of this new publication — designated Bulletin WD-60 — are availabl on request.

Circle Reader Service Card 99

— *m w j* —

REPUBLIC AVIATION SPENT $155 MILLION IN 40 STATES

An increase of almost 34 per cent in business done with sub-contractors and vendors during 1960 has been reported by Republic Aviation Corp., Farmingdale, L.I., N.Y.

In a year-end statement the company says it spent $155,-700,000 with 4200 firms throughout the country to obtain components, parts, and supplies to support production of the Air Force's new F-105 fighter-bomber. The figure for 1959 was $103,000,000.

According to the report, the firms are located in 40 states, Washington, D.C. and in Canada. New York state ranked number one with the total amount spent reaching $49,700,000. California came in second, followed by Kansas, Iowa, Pennsylvania, New Jersey and Ohio. The report shows that 302 of the firms were listed as sub-contractors and the remaining 3898 as suppliers of standard or vendor designed equipment.

—*mwj*—

FUND DECLARES DIVIDEND, ELECTS DIRECTOR

Directors of Samson Convertible Securities and Capital Fund, Inc., Briarcliff Manor, N.Y., have declared a dividend of 25 cents per share from net investment income and a distribution of 48 cents per share from long term capital gains.

Dana W. Atchley Jr. was elected a director of the Fund. "Mr. Atchley, president of Microwave Associates, Inc. for the past eight years, brings with him to the Fund, valuable experience as the head of an exceptionally successful microwave component company," said Mirek J. Stevenson, president of the Fund.

During the past year the Fund has stressed investments in areas of scientific technology. The addition of Mr. Atchley to the board is in line with the management's philosophy of having practicing scientists evaluate scientific companies, Mr. Stevenson added.

—*mwj*—

Electronic Design Engineers

The new Canoga Park Division of Space Technology Laboratories, Inc., located in Los Angeles' West San Fernando Valley, offers outstanding opportunities to design engineers and electronic engineers with transistorized circuit design experience.

Transistorized Circuitry Design Engineers
BS or advanced degree in EE for design, development, packaging, integration and test of electronic circuitry and test equipment for infrared tracking systems, and for a study program in advanced signal modulation techniques. A strong theoretical background to analyze problems connected with the design and development of transistorized circuitry is required. A wide and varied experience in transistorized circuit equipment is desirable, as is experience in the design and development of similar equipment from original concept through system integration and test.

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ELECTRONIC TUBE DIVISION ELMIRA, NEW YORK

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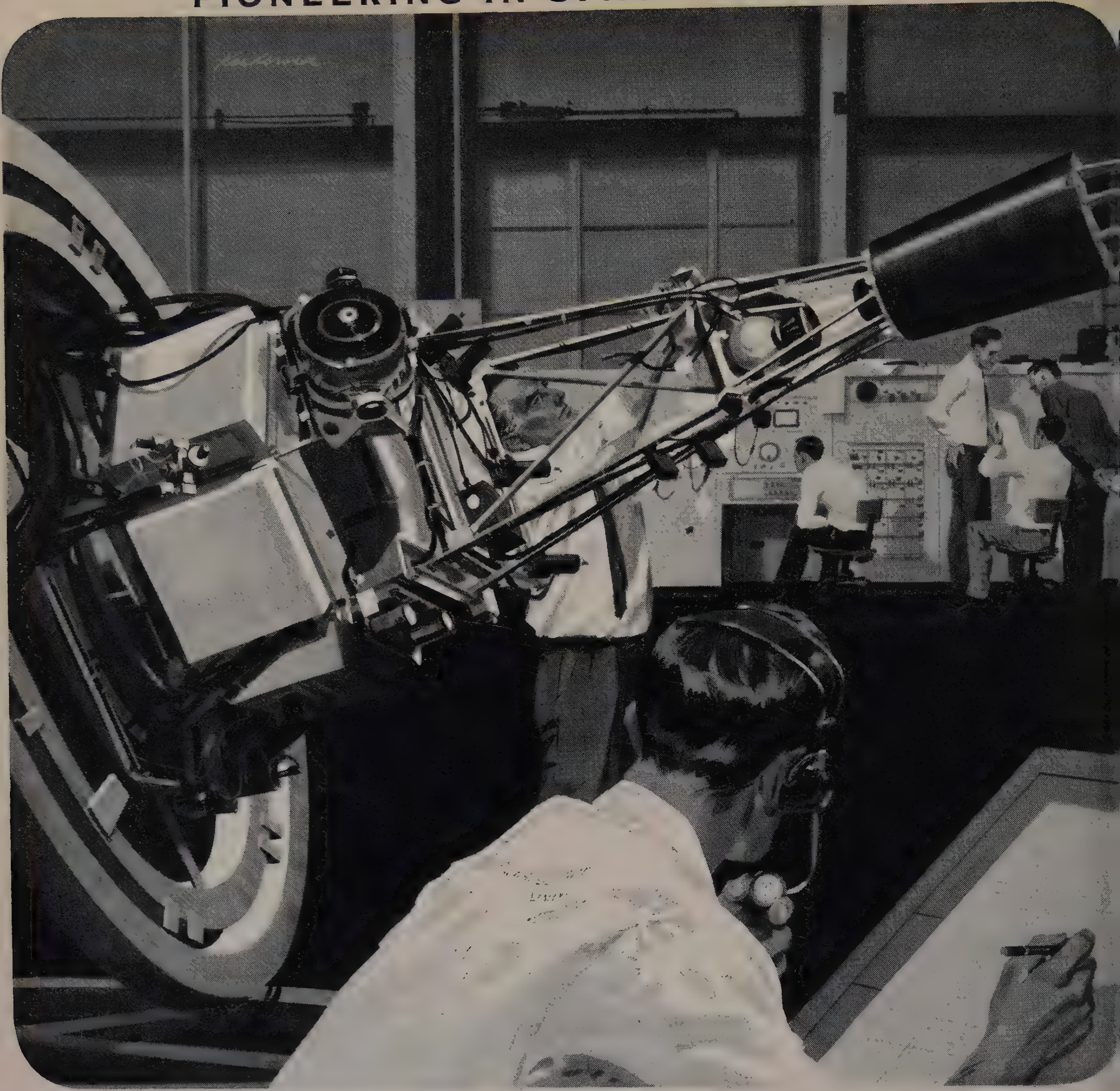

DEVELOPMENT OF LUNAR SPACECRAFT

The "Ranger" series of spacecraft, designed first to explore the environment and later to land instrument capsules on the Moon, are now being developed and tested at Jet Propulsion Laboratory.

Illustrated is a "Ranger" proof-test model undergoing design verification testing at the Laboratory. Here design features are tested and proved, operational procedures developed and handling experience gained for the actual construction of the initial flight spacecraft.

This is one phase of JPL's current assignment from the National Aeronautics and Space Administration—to be responsible for the Nation's unmanned lunar, planetary and interplanetary exploration.

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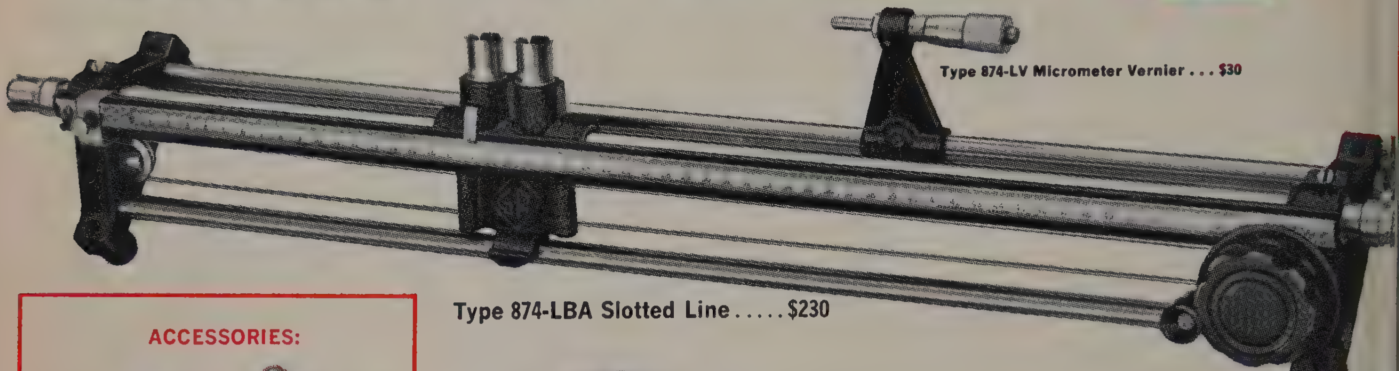
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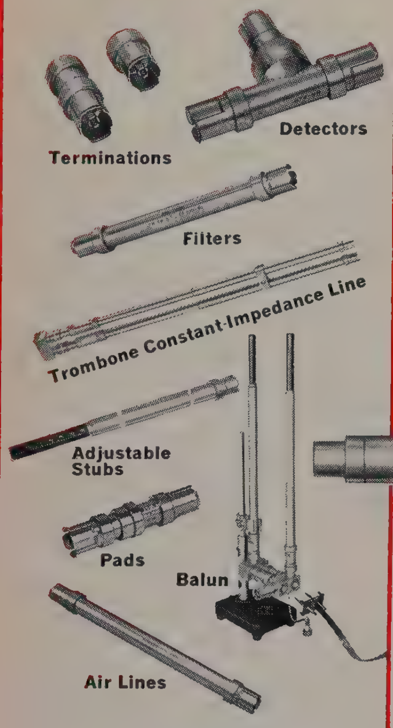

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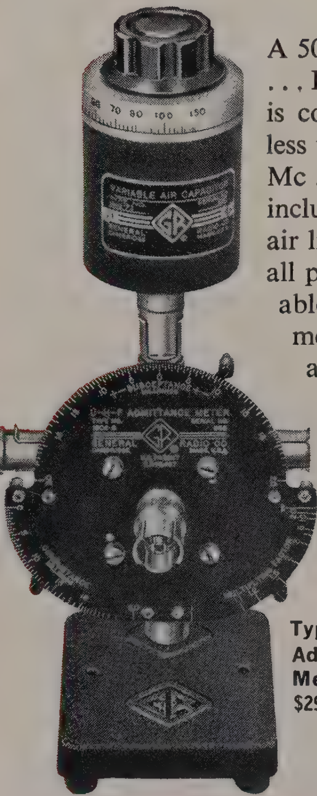
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Type	Frequency Range	Price
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DNT-2	40 to 280 Mc	$645
DNT-3	220 to 950 Mc	$693
DNT-4	870 to 2030 Mc	$898

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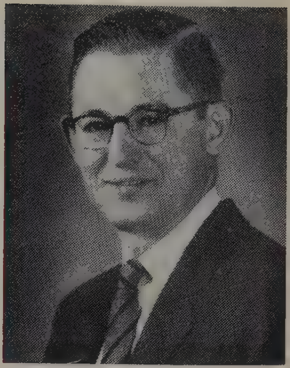
MICROWAVES in the next decade

". . . SOLID STATE RESEARCH . . . WILL HAVE A STRONG ROLE IN THE . . . ADVANCEMENT OF MICROWAVE TECHNIQUES . . ."



BENJAMIN LAX*
ASSOCIATE EDITOR
the microwave journal

It is appropriate in this year 1961, the beginning of a new decade, to contemplate the future of microwave science and technology.

The two preceding decades have seen a veritable explosion in this field of science. World War II gave birth and provided a tremendous impetus to the development of the microwave art for radar and communications. The next decade of the 1950's was even more remarkable, partly spurred on by peacetime objectives and partly stimulated by the cold war. These two decades mark a period of invention, innovation and scientific achievement in microwaves which perhaps may not be matched in the periods to follow.

Nevertheless, although the new developments may be fewer and less frequent, their practical importance and scientific significance can be far reaching. The emphasis to a large degree will be undoubtedly on the application of microwaves to space projects which to all intents and purposes are really just beginning. The other development that will have a strong role in the application and advancement of microwave techniques is in the area of solid state research. In the first it is not difficult to visualize the future; in the latter, the crystal ball is more hazy.

From the commercial viewpoint, the future is bright since practical microwave components and systems are going to make important contributions in the future of our space projects. As we send vehicles deeper and deeper into outer space, we are going to require more powerful transmitters and more sensitive receivers to maintain communications with these fast moving vehicles. Microwave frequencies seem ideally suited to meet this problem. In order to provide the large gain necessary for transmitters based on the ground, the shorter the wavelength, the higher the gain of the large dishes which are getting bigger and bigger all the time. Great parabolic reflectors exceeding 100 feet in diameter and approaching the 600 foot dish at Sugar Grove, Virginia, are bound to become more numerous. Of course there are practical limitations to size and frequency prescribed by mechanical tolerance on these large reflectors as the frequencies increase. Another limitation is the power available in the transmitting tubes and our ability to handle them in practical wave guide and transmission lines. For this reason, frequencies in the 3 to 10 kilomegacycle range are destined to be the favored ones.

Undoubtedly progress will be made in building higher power klystrons, amplitrons and even new types of devices which may increase the average power level by another order of magnitude in the next decade. Perhaps it will not be an electron tube. but a solid state transmitter which may provide the solution to the demands for even greater power. However, at present our technology indicates that the next step is with improved and better electron tubes. The solid state transmitters, of course, will be a natural for the beacons and the transmitters that are destined for the interstellar vehicles. Insofar as receivers are concerned, the masers and parametric amplifiers seem to be adequate and these will undoubtedly improve. Increased bandwidth and greater stability to match in engineering performance the highly developed microwave component of the preceding decade will make these devices more attractive. The use of masers and parametric amplifiers will undoubtedly dictate a new design of the large antennas to match the low noise characteristics of these solid state receivers so that the latter can be used to greater advantage. The use of Cassegrain systems to minimize transmission losses between the output horn and the receiver, may be favored in order to reduce the system noise even further. In some cases, possibly the use of giant horns with a large aperture will solve these problems.

How about the new exciting and fundamental developments which we can hope for in the field of microwaves? Can we expect to see such startling developments as those represented by the discovery of microwave resonance phenomena, the ferrite devices, paramagnetic maser and the parametric amplifiers? These indeed are hard to predict; but *journal* editorials have never been known to shrink from "going out on a limb."

One of the areas where there is some promise of exciting developments is in the more conventional type of solid state amplifier. For some time now engineers in the semiconducting field have been trying to increase the frequency response of the diodes and transistor with some successes. For the most part, this effort has

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** Head, Solid State Division, Lincoln Laboratory, a Center for research operated by Massachusetts Institute of Technology, with the joint support of the U.S. Army, Navy and Air Force.*

fallen short of the microwave frequency range with the exception of the parametric and the Esaki diodes. The latter has been extended to 100 kilomegacycles. However, no one has seriously attempted to look for new transistor materials whose characteristics would more nearly fulfill the needs for this high frequency range. It is a simple basic physical fact that the electron collision loss at room temperature in most solids is sufficiently high that the Q of the semiconductor itself is generally less than unity. If pure enough material at lower temperature is used, then Q can be raised as high as 10 or even possibly 100. Also the transport time in which the physical dimensions is the limitation, can be improved by increasing the carriers mobility in the proper material. Both of these factors indicate that the future of high frequency transistors and diodes lies in the use of low temperature, low gap materials, which should exhibit high mobility and low losses. This, of course, can only be realized when these materials are properly prepared and selected from the host of known semiconducting compounds as well as semimetal elements and alloys.

A new intriguing technique for fundamental investigations is the combined use of optical excitation and microwave resonance in solids. Already it has been possible to modulate light in ruby by microwave resonance and thereby measure the spin of the optically excited state in this material. A variation of this technique in many paramagnetic crystals and other materials as well will undoubtedly provide much new fundamental information about these solids. Resonance phenomena at microwaves utilizing ultra-high pressures has already started and will continue to flourish in the next decade. Still another variable, of equal importance in this regard, is the use of ultra-low temperatures below 1° absolute by means of He^3 cryostat or adiabatic demagnetization which will permit magnetic and cyclotron resonance in materials with very small impurities to be investigated. Ultra-sonic generation at microwave frequencies will find use not only as a tool for studying the phonon spectrum in these materials, but will undoubtedly have practical consequences for new devices involving ferrimagnetic, paramagnetic and semiconducting materials and perhaps even metals.

Finally, although we have previously discussed the future of millimeter waves, it is nevertheless one of the most important future developments of the microwave field. This range of the spectrum will be more fully exploited both from a practical viewpoint as well as a tool for fundamental research. For communication and radar systems, the use of millimeters in outer space is no longer limited since one can rise above the atmosphere and eliminate water vapor absorption as well as those by oxygen. The possibilities for communication, radio astronomy and radiometry under these conditions become extremely inviting. The use of masers which are now available at these frequencies has increased the overall sensitivity by more than one order of magnitude over that of conventional receivers. Nonreciprocal devices using for the first time antiferromagnetic materials will be further exploited in the next few years. Communication systems on the ground over special cylindrical wave guides will handle broad banded high capacity systems up to 100 kilomegacycles. The possibility of utilizing Cerenkov radiation for generating microwaves and millimeters may become a practical reality in the not too distant future. The medium that will provide most successful results may be a plasma or possibly a ferrimagnetic material whose properties can be readily adjusted by an external magnetic field.

In the area of fundamental investigation resonance phenomena deeper into the millimeter and submillimeter region will be made possible by two important developments that are coming to fruition within the next two or three years; namely the development of higher power millimeter tubes, as fundamental sources up to 300 kilomegacycles which should even permit harmonic generation in the submillimeter range. The other development is the use of high magnetic fields of the order of several hundred thousand gauss which will permit millimeter resonance in materials heretofore not investigated and also the extension to existing materials with greater resolution. Lastly, this frequency range will make more extensive use of interferrometers and techniques similar to those used at optical wavelengths.

The most exciting things to come are those which we have omitted because we are unable to visualize or predict them at this time. These unknown breakthroughs are bound to come and will undoubtedly alter microwave research and development in an unexpected fashion.

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